



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

January 6, 1984

SUBJECT: Monitoring and Assessing Quality
of Screwworm Strains

TO: J. Dominguez
R. Garcia
E. Gersabeck
L. Hernandez
D. Hoffman
C. MacVean
R. Marroquin
A. Martinez

During the 2nd and 3rd weeks of December I spoke with several persons in Production and Methods Sections about the use of simple life table statistics to monitor the quality of screwworm strains on a continuous basis. I feel that such data would be valuable in helping to decide whether a change in strain is advisable.

I attach a proposal which I would like you to consider.

RICHARD J. BRENNER, USDA-ARS
Research Entomologist

cc:

✓ O. H. Graham

Enclosure

PROPOSAL FOR THE USE OF LIFE TABLE STATISTICS TO MONITOR
QUALITY OF CURRENT AND CANDIDATE STRAINS
OF STERILE SCREWORM

R. J. Brenner
USDA-ARS

In December 1983, personnel of APHIS, the Commission, and ARS met to determine whether a change in strain was advisable. The decision to retain the A-82 strain signaled a change in policy, and indicates that future decisions will rely heavily on available data which compare the current strain in production with the candidate strain(s).

One aspect of strain evaluation examines changes that have occurred in the current strain during the past year, and whether these changes are indicative of strain "deterioration". Data from rearings of the candidate strain are used to assess how well it is adapting to the colonization procedures. In both instances, we can examine the characteristics and fitness of each strain, using simple life table statistics, to estimate their net reproductive rates (R_0). This memo will propose the use of R_0 to monitor the quality of strains in Production on a continuous basis, and as a standard to assess the adaptability of candidate strains in Methods.

Net reproductive rate is defined as the number of females produced per female per generation. It is derived by multiplying (1) the average fecundity of a female, (2) the sex ratio of the offspring, and (3) the probabilities of surviving each life stage. Additional parameters are included to estimate the propensity of a female to mate and oviposit. An R_0 value of 1 implies a stable population that neither increases nor decreases from generation to generation. A value less than 1 implies that colonization is not feasible, while a value greater than 1 indicates that the population size will increase per generation by a factor equal to the R_0 value. In the case of the strain in Production and in Methods, R_0 obviously will be much greater than 1. The usefulness of R_0 will lie in evaluating and monitoring its parameters. All parameters can be incorporated into a simple mathematical equation:

$$R_0 = F \times Ph \times Si \times Pf \times Sa \times PF = \text{no. fem./fem./generation, where}$$

F= fecundity at reproductive age,
Ph= proportion of the eggs that hatch,
Si= proportion of immatures that survive larval development,
Pf= proportion of population that is female,
Sa= survival of females to reproductive age, and
PF= proportion of fecundity realized.

The parameter PF can easily be estimated by:

$$PF = \frac{\text{grams of eggs deposited}}{\text{expected grams of eggs if all surviving females would oviposit.}}$$

Alternatively, PF can be estimated by multiplying the proportion of females that mate by the proportion of the mated females that oviposit.

Most of the measurements needed to compute R_0 are already being made in both Production and Methods Sections. With existing data, I was able to compute R_0 for the A-82 strain in Production, and for the O-83 strain in Methods; I present these data here only as an example of how R_0 is computed, and how

it might be used to trouble shoot or compare strains. The parameters Ph and Si were combined for the A-82 strain, because separate estimates were not readily available. The comparison is presented below.

STRAIN	F	x	Ph	x	Si	x	Pf	x	Sa	x	PF	=	Ro
O-83	220		.90		.55		.5		.85		.27		12.5
A-82	220		1	.54	1		.5		.85		.44		22.2

Although some estimates were used by both Production and Methods (F, Sa), some differences are apparent that have resulted in large differences in the estimates of Ro. The product of Ph and Si is .495 for O-83 and .54 for A-82. This is the result of a higher proportion hatch for A-82 (.97, according to R. Marroquin), and may reflect actual differences between strains, or possibly, differences in the techniques of measuring proportion hatch. The greatest disparity in parameters lies in the proportion of fecundity realized (PF). In both instances, this was estimated using the number of grams of eggs collected per cage divided by the expected number (assuming 100% mating and oviposition). Differences could reflect differences in procedures used by the two Sections. However, differences may reflect the greater adaptation of A-82 to the mass rearing methodologies, and the continuing adaptation of O-83. As a result, adults of A-82 are more likely to mate and oviposit, resulting in a higher proportion of fecundity realized. This could also account for the higher proportion hatch exhibited by the A-82 strain.

Since a new cohort is begun three times each day, new estimates of Ro can be computed for each shift. Any endpoint can be used, but all data must be collected from the same cohort. For example, if we use an egg as the endpoint to estimate proportion fecundity realized (PF), we must "work backward" to find the proportion of those females that survived to reproductive age (Sa), the proportion that survived larval development (Si), and the proportion that hatched (Ph). In addition, dissections of females at reproductive age must be undertaken in order to accurately estimate the average fecundity.

Trends can be plotted and analyzed by examining estimates of each parameter over time. For example we can plot the average fecundity for the past 30 days. This would involve $30 \times 3 = 90$ data points. A regression equation can be computed and we can test to determine whether the slope of the line (i.e. change in fecundity) differs significantly from 0. If so, the value of the slope will indicate the direction and magnitude of change. To help trouble shoot, significant changes over time can then be correlated with changes in procedures or changes in materials that occurred during that period. Similarly, regression equations for each parameter can be compared month to month or year to year. This technique will also enable us to compare strains parameter by parameter.

I must stress that the examples given in this memo are based on rough estimates and should not be construed as factual. Clearly, methods for collecting data for each parameter must be scrutinized and finely tuned. I would like to spend some time in the plant in both Production and Methods, dissecting gravid females to obtain more accurate estimates of fecundity, and determining the ease with which this project could become an integral part of within-plant quality control. I would also like access to data from previous months and years to test the hypothesis that strain deterioration (or adaptability) can be detected using simple life table statistics to estimate Ro.

D. H. Graham

January 10, 1984

Ref: PGD'010

To: DR. RONALD E. LOWE
Sub*Director of Production.

Subject: Periodic Report. Research and Experimental Development Dept.

Dr. Robert L. Mangan, Research Entomologist, ARS, Tuxtla Gutierrez, has presented this department a summary (see attachment I) of his evaluation of the effect of possible contamination of O-83 with Production flies (A-82).

Although Dr. Mangan's report indicates a remote effect due to possible contamination, we are envoking policies to continually reduce the possibility of contamination. We, too, are concerned with the possibility of the introducing a parasite or pathogen into the colony. However, our procedures for security provides a good first line defense against this possibility. It is extremely important that each new strain be thoroughly monitored for any evidence of a pathogen and or parasite as this is the most probable avenue of introduction.

Mass rearing of insects is a relatively new science and we are for most part at the mercy of "taking-what-we-get" rather than defining specific desired criteria and then actively breeding strains to meet our needs, as we do with domestic plants and animals. It is, therefore extremely important that we mechanize and increase the efficiency-reliability of our present rearing system to provide time to explore more productive rearing systems and more useful insect strains.

Dr. Richard J. Brenner, ARS, Research Entomologist has presented a memo on "Monitoring and Assessing Quality of Screworm flies" (see attachment II). This memo provides a unique method for tracking and comparing quality of insect strains. We are currently studying this system for use in monitoring and assessing production and backup screworm strains. It could be a powerful tool in comparing strains to aid us in determining when strains should be changed.

We extend our appreciation to Drs. Mangan and Brenner for providing valuable assistance to the screworm program.

January 10, 1954
Ref: PCD'010

To: Mr. RONALD E. LOWE
Sub-Director of Production.

Subject: Periodic Report, Research and Experimental Development Dept.

Dr. Robert L. Mangan, Research Entomologist, ARS, Tusula Outlets, has presented this department a summary (see attachment I) of his evaluation of the effect of possible contamination of 0-87 with Production files (A-82). Although Dr. Mangan's report indicates a remote effect due to possible contamination, we are invoking policies to continually reduce the possibility of contamination. We, too, are concerned with the possibility of the introducing a parasite or pathogen into the colony. However, our procedures for security provide a good first line defense against this possibility. It is extremely important that each new strain be thoroughly monitored for any evidence of a pathogen and or parasite as this is the most probable avenue of introduction.

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Dr. Richard J. Brenner, ARS, Research Entomologist has presented a memo on "Monitoring and Assessing Quality of Screwworm flies" (see attachment II). This memo provides a unique method for tracking and comparing quality of insect strains. We are currently studying this system for use in monitoring and assessing production and backup screwworm strains. It could be a powerful tool in comparing strains to aid us in determining when strains should be changed.

We extend our appreciation to Drs. Mangan and Brenner for providing valuable assistance to the screwworm program.

STRAIN CHANGE PROGRAM: (Felipe de la Cruz. Program Supervisor).

- 1st. major review of facility with contractor (Pedro Gonzalez) and the Engineering and Maintenance Department revealed the facility about 98% completed. Quality of work was better than expected. Mr. Gonzalez worked with our department in a very difficult situation in having to coordinate his work with our rearing of 0-83. I am pleased with Mr. Gonzalez's work and cooperation. I would recommend him for other contracts. We are working with him in completion of final details.
- UM-18 blower servicing the larval rearing floor broke down. January 3, 1984 a new fan was ordered from Monterrey the same day. The extraction unit for this area is providing a vacuum which is drawing air through the heating coils and holding temperatures up to 82°F (ie. 13° low). RH is holding at optimum (70%).
- New rack construction by Engineering & Maintenance Department is on schedule.
- I will be meeting with Mr. Henri Charpentier to check final design of larval rearing gutter with the modified design of the standard vat to ensure exact fit.

The program supervisor presented an extensive list of items to organize and streamline his rearing operation.

Temperatures and R.H. were very erratic (71-83°F and 39-51% RH) (optimum is 78°F and 50% RH) apparently caused by a manually controlled damper. Engineering and Maintenance is installing an automatic-thermostatic controlled damper.

Temperatures in pupation are low (ie. range 70-80°F) (optimum 82°F). R.H. slightly high (55-60% RH) (optimum 50%). There is no thermostat on the heating coil. We have requested this to be installed by Engineering and Maintenance Department.

Temperatures in pupal maturation are low (72-74°F) (optimum 78°F). This is caused by (1) no thermostat to heating coil; (2) no injection of air because blower is not serviced by electricity and pulley size of V-belt to fan is not of a proper size. We have issued work orders to Engineering and Maintenance Department.

Temperatures and RH in oviposition room are low (70°-78°F; R.H. 58-78%) (optimum 80°F, 80% RH); caused in part by installation of new doors.

STRAIN CHANGE PROGRAM: (Felipe de la Cruz, Program Supervisor).

--- last major review of facility with contractor (Boris Gerasimov) and the Engineering and Maintenance Department revealed the facility about 98% completed. Quality of work was better than expected. Mr. Gerasimov worked with our department in a very difficult situation in having to coordinate his work with our testing of 0-33. I am pleased with Mr. Gerasimov's work and cooperation. I would recommend him for other contracts. We are working with him in completion of final details.

--- 0-18 blower servicing the larval testing floor broke down. January 3, 1984 a new fan was ordered from Monterey the same day. The extraction unit for this area is providing a vacuum which is drawing air through the heating coils and holding temperatures up to 32°F (ie. 13° low). It is holding at optimum (70%).

--- New rack construction by Engineering & Maintenance Department is on schedule.

--- I will be meeting with Mr. Henri Charpentier to check final design of larval testing gutter with the modified design of the standard vat to ensure exact fit.

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Temperatures and RH in repositioning room are low (70-78°F; R.H. 55-75%) (optimum 80°F, 60% RH); caused in part by installation of new doors.

Periodic Report.

January 10, 1984.

Page No.3

2nd. Initiation temperature-humidity at optimum (98°F, 70% R.H.)

We are using 1st. Initiation room to store dry diet until Tri-Clover system is installed.

No word about Tri-Clover System crossing border. We are using a temporary hose to obtain mixed diet from Production in addition to our mixer.

A guard was placed at the door between Methods and Production area to record and supervise entry-exit. This has reduced theft-vandalism. A bell and lock will be tested.

POST-IRRADIATION PROGRAM:(Biol. Rosario Cortez Melendez).

Percent emergence of 0-83 irradiated flies for December 22-28, 1983 was 88.60% (see attachment IV) As mentioned before, this program does not have sufficient personnel to conduct a full range of Quality Control tests on both A-82 and 0-83. We will be hiring 20 positions for this program in February, but will need two more to provide full Quality Control tests on 0-83.

Format of the Quality Control report for A-82 is being revised to simplify the data presentation.

Work requests have been issued for regrouting floor tile, painting, sink faucet-drain hook ups, electrical hook up, and completing repairs in the walkin incubator of the new laboratory.

See Production weekly activity report for 0-83. (attachment III). Difficulties with temperature and humidity are reflected by our production figures for 0-83.

FIELD TESTING PROGRAM: (Raul Selvas. Program Supervisor).

Vehicles for this program have been submitted to Engineering and Maintenance for servicing.

Dr. Raul Selvas has returned from vacation and is preparing for the next field test at the end of January 1984.

Senior Rene Garcia and Charles MacVean are in the Yucatan looking for two field testing areas for A-82 and 0-83. They are to return January 11, 1984.

We completed the review of the mobile field testing labs and have sent our suggestions to Mr. Walter Rice and his counterpart. We will need 2-field labs in order to conduct field tests on the Production and candidate strains at the same time.

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FIELD TESTING PROGRAM: (Raul Seivas. Program Supervisor).

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Vehicle damaged in Emiliano Zapata was returned and will be submitted to Engineering and Maintenance for estimation of repair.

PRE-IRRADIATION PROGRAM: (Raquel Courtois. Program Supervisor).

Final drawing of the experimental rearing vat (ie. Modified designs of previous experimental vat) is to be completed early this week. 100 vats will be ordered.

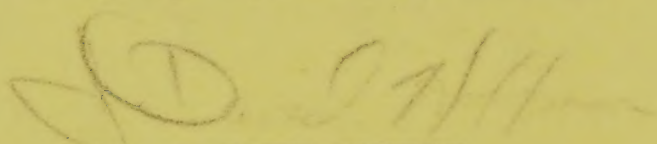
Vat racks and vats are to be set in place by Engineering & Maintenance.

Review of this programs activities will take place at end of this month so as to establish Quality Control tests.

COMMENTS AND REFLECTIONS:

A higher level of responsibility, authority and accountability will be placed on Program supervisors. They will be individually counscelled in a series of weekly meetings starting immediately. We will help them take the lead in all matters affecting their respective departments. This should greatly increase the capacity and quality of work in this department as well as boost morał in the ranks.

A statistical position for designing experiments, and providing analysis of data is being requested for Methods.


DR. J. DAVID HOFFMAN
Chief of Research and
Exp. Development Dept.

c.c.p. Dr. Robert Mangan.
c.c.p. Dr. Richard Brenner
c.c.p. Dr. H. Graham.
c.c.p. Dr. R. Bram
c.c.p. Files.

Vehicle damaged in British tests was returned and will be submitted to Engineering and Maintenance for estimation of repair.

PRE-IRRADIATION PROGRAM: (Rasael Controls, Program Supervisor).

Final drawing of the experimental testing vat (ie. Modified design of previous experimental vat) is to be completed early this week. 100 vats will be ordered.

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DR. J. DAVID NORMAN
Chief of Research and
Exp. Development Dept.

c.c.p. Dr. Robert Mangum.

c.c.p. Dr. Richard Brennan.

c.c.p. Dr. E. Graham.

c.c.p. Dr. R. Bram.

c.c.p. Elise.



United States
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Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
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December 28, 1983

TO: Management Personnel in Methods
Development and Production

Enclosed is a summary of my reasons for suggesting that the possible contamination of O-83 within production flies, and other incidences of past or future contamination of 10 or less flies entering populations of 100's of thousands or millions, is not likely to have effect on the performance of a new strain.

I mentioned this during our 8 Dec. meeting. I would like to submit this document for the weekly report. I will also revise this slightly and submit a manuscript with citations etc. to the APHIS publication series.

ROBERT L. MANGAN
Research Entomologist

In recent technical meetings, the topic of possible contamination of new strains with genetic material from the old and better plant adapted strain has been discussed. This genetic contamination was mentioned during the V-81 - A-82 change over when A-82 suddenly lost larval size, and in December 1983 due to the poor isolating barrier between O-83 flies in Methods and Development and the main production areas.

The purpose of this note is to outline, with some degree of scientific formality, the probabilities of significant change in the genetic structure of the strain in Methods due to contamination. The formulas and mathematical models used here were developed by J. B. S. Haldane and R. A. Fisher in the 1920's and 1930's, by S. Wright for the 1930's to the present and by M. Kimura in the 1950's and 1960's. The major questions these population geneticists and statisticians addressed are: What is the probability that a new advantageous, or detrimental gene will ultimately survive in a population? and; How many generations will be ~~required~~ for this new gene to increase to a certain frequency if it has a known selective advantage?

This body of theoretical work is largely not realistic for natural populations for a number of reasons. The reproductive structure (mating patterns, number of off spring etc.) age structure, (immature, reproductive and senescent, etc.) and ecological factors affecting rates of selection and population fluctuations are seldom known with adequate precision to make any calculations reliable. The values for calculating probabilities and rates of genetic changes are, however, frequently available for domestic animals, crop plants and some human populations. Agricultural and medical geneticists have relied fairly heavily on this body of theory.

Data used in calculations:

Adult population size (per week)

Number of cages with adults	42
Number of liters pupae/cage	6
Number of pupae/liter	10183
Ne = Effective number of adults	2,566,116

Total population-size liters pupae produced per day	300
liters pupae produced per week	2100 liters
N = Total weekly population pupae	21,384,300

Gene frequencies of contaminants.

1 unmated female enters adult population

or

$$p = \frac{1}{2566116}$$

1 male enters adult population and mates once = .0000004

1 mated female enters adult population

or

$$p = \frac{2}{2566116}$$

1 male enters adult population and mates twice = .0000008

In general, the frequency of contaminants genes = $\frac{nc}{Ne}$

= The number of times contaminants are represented/effective population size.

Attached.

Calculation of 'Fate' of Contaminant Genes

I. What is the ultimate probability that a contaminant gene with a selective advantage (=s) will survive in the population?

R. A. Fisher and S. Wright have shown that if $N_e = N$, then the ultimate survival probability is $2s$, that is twice the selective advantage. For this data $N_e = .12 N$, the corrected formula, then, is

$$u = 2s \left[\frac{N_e}{N} \right]$$

the lower limit of values for s in order for the contaminant gene to have a significant (>5%) chance of even surviving in the Methods strain require that this gene would have to have approximately a 25% advantage in the heterozygotes condition. This I would estimate is 10 higher than any reasonable estimate of selective advantage. A series of probabilities of survival for different s values are given in Table 1.

If the gene is advantageous but recessive, a condition which I think is more likely (see Note 1), the probability of ultimate survival is:

$$u = \sqrt{\frac{2s}{\pi N_e}}$$

In this case only homozygous contaminants have a selective advantage and, again for $s = .25$ and $N_e = 2,566,116$

$$u = \sqrt{\frac{2(.25)}{\pi(2,566,116)}} = .00025$$

Kimura has calculated intermediate probabilities and has shown that for low degrees of expression of a contaminant in heterozygotes a 10x increase in expression results in approximate doubling of probability of survival.

In summary, the ultimate probability that a migrant contaminant in the Methods population will survive is extremely small (less than 1 in 100) if the selective advantage of this gene is within the expected normal range (1 to 5% advantage). If the gene is recessive the probability is much smaller (less than 1 in 1000) no matter what the selective advantage is. In order to have a statistical probability of survival, contaminant genes must have high expression in heterozygotes and greater than 25% selective advantage over the methods population.

II. Assuming that the migrant contaminant survives (or is repeatedly introduced) now long will it take for the contaminant gene to spread through the population?

With no dominance of contaminant or strain genes, the proper formula for calculation of number of generations is

$$t = \frac{2}{s} \ln \left[\frac{P_t (1-P_o)}{P_o (1-P_t)} \right]$$

With t = number of generations, s = selective advantage, P_t = frequency of contaminant at generation t , and P_o = initial contaminant frequency. This formula is only strictly accurate for lower selection values but assuming slight error for large values the number of generations can be calculated.

The initial frequency (P_o) is assumed to be $n/Ne = n/2,566,116$ for n contaminant flies. Table 2 gives the number generations and number of years necessary for the frequency of contaminants to reach .10 and .15 for 3 and 10 contaminants per 7 day period. Three adult contaminants would equal 3 unmated females, or 1 mated female and 1 male that mates once, or 1 male that mates 3 times, etc.

Attachment I

If a gene frequency of 10% contaminants would be required in order to detect the contamination effects, even at a selective advantage of 30%, 83.6 generations would be required to detect contamination if 3 adult equivalents entered a colony cage. More than triple the contamination rate to 10 adult equivalents reduces the time to 68.4 generations, giving less than 20% reduction in time (see Note 2).

Conclusions

The calculations I have presented here are based on fairly reliable information provided by the personnel in Methods and Development. An important question is how errors in these measurements may might affect the probability and time necessary for contaminants to be effective. One possibility of error is in N_e , the number of adults in the colony. If the number of cages were 36 rather than 42, about 14% less adults would be present. If production remained at 21.4 million, N_e/N would be reduced to .10 resulting in a negligible probability reduction. The probability of survival of a contaminant with .10 advantage would then be .020 rather than .024. The time necessary to reach a significant frequency would be reduced in a similar manner.

A final note should be made concerning other types of contamination. At present isolation of Methods colonies from the plant is not adequate. As strains are collected from areas more central to screwworm populations, the prevalence of fungal, bacterial and viral diseases is expected to increase. A well known dogma of biogeography is that parasitic diversity increases toward the center of the range of a species. Without attempting to sound like a doomsday predictor, I think that the possibility of a diseased or parasitized strain entering the plant is a very likely consequence of poor isolation between the Methods section and production. An outbreak of a

wasp parasite such Nasonia vitripennis which periodically infests the Fargo, N. D. laboratory would make our housefly problem appear as nothing.

All the calculation above used N_e as the number of adults in the colony at full production. During the two to three generation period of expansion, when a new strain is first turned over to Methods, contamination may have more serious consequences. A contaminant entering a population of 10,000 flies could, with a selective advantage of $s = .30$, increase to a frequency of .50 in only 61.40 generations (= 3.5 years). While this is still much shorter than the time to test and use a strain, these calculations do show that the smaller the colony population, the more serious the consequences of contamination.

Table 1.

Probability of ultimate survival of migratory contaminant genes entering the
Methods Development population with positive selective advantage, a large
Methods population, and $N_e = .12N$

Heterozygote Selective Advantage	.01	.05	.10	.25	.30
Prob. of Survival	.0024	.012	.024	.060	.072

Table 2.

Number of generations required to change gene frequency of mutant contaminant from P_0 (= number of contaminants/total adult population) to P_t (= 10% and 15%) for varying selective coefficients(s) and varying number of contaminants.

A. For 3 adult contaminants per 7 days

To final frequency of:	Selective coefficient(s)					
	.01	.03	.07	.1	.3	
.10	2506.9	835.6	358.1	250.7	83.6	generations
	144.2	48.1	20.6	14.4	4.8	years
.15	2599.4	866.5	371.3	259.9	86.6	generations
	149.5	49.9	21.4	15.0	5.0	years

B. For 10 adult contaminants per 7 days

To final frequency of:	Selective coefficient(s)					
	.01	.03	.07	.10	.30	
.10	2051.6	683.9	293.1	205.2	68.4	generations
	118.0	39.3	16.9	11.8	3.93	years
.15	2144.1	714.7	306.3	214.4	71.5	generations
	123.4	41.1	17.6	12.3	4.1	years

Note 1. Here I give reasons for assuming genes for plant adaptation which include traits such as small size and faster development as well as the possibility of poor performance in the field are recessive. Two strains in recent times have apparently been "bad" genetically, based on poor performance in the field and great program improvement when they were replaced. The observation was given by Mr. Sudlow and Dr. Meadows as well as others who have experienced strain deterioration that "when strains start to go bad, they go quickly". Recessive genes are selected more quickly as their frequency increases since the probability of an individual being homozygous for the recessive and enjoying this advantage increases. Dominant genes are selected for quickly at first then much more slowly. For example, time to change an expressed dominant character (phenotype) frequency from .01 to .50, with selection of 10% favoring a dominant gene in a large population, is 48.2 generations. To change from .50 to .99 frequency of the same gene with the same selection would require 116.6 generations. The same selection acting on phenotype frequency of recessive genes requires 116.6 generation to move from .01 to .50 and 48.2 generations to move from .50 to .99. Thus observed changes in performance of populations in the plant seem to fit a recessive mode of inheritance.

Note 2. A question which should be raised here is: How do strains go bad given that contaminants (and mutants) will have such low survival probability and will take so long to become established? Two factors are important in this consideration. First, even under the best conditions on hydroponic diet and usually on meat diets, laboratory screwworms are about 70% as large as wild screwworms. Second, genes for early crawl off and small size, in order to survive when media is bad, are probably adaptive for a parasite such as the screwworm which frequently kills its host. I feel that genes for laboratory or plant adaptation are present at relatively high frequency in wild populations. Rearing these flies under stress probably selects against genes which keep these traits from being expressed except under stress while, at the same time, increasing the frequency of these traits. At present in our laboratory we are investigating the modes of inheritance of laboratory adaptation. I feel quite confident in believing at present that plant adaptation and loss of performance in the field is due to selection for expression of traits which are already present. This selection, at present, is an inevitable result of rearing screwworms on media other than live animals.



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

January 6, 1984

SUBJECT: Monitoring and Assessing Quality
of Screwworm Strains

TO: J. Dominguez
R. Garcia
E. Gersabeck
L. Hernandez
D. Hoffman
C. MacVean
R. Marroquin
A. Martinez

During the 2nd and 3rd weeks of December I spoke with several persons in Production and Methods Sections about the use of simple life table statistics to monitor the quality of screwworm strains on a continuous basis. I feel that such data would be valuable in helping to decide whether a change in strain is advisable.

I attach a proposal which I would like you to consider.

RICHARD J. BRENNER, USDA-ARS
Research Entomologist

cc:

O. H. Graham

Enclosure

Atchinal 74

PROPOSAL FOR THE USE OF LIFE TABLE STATISTICS TO MONITOR
QUALITY OF CURRENT AND CANDIDATE STRAINS
OF STERILE SCREWORM

R. J. Brenner
USDA-ARS

In December 1983, personnel of APHIS, the Commission, and ARS met to determine whether a change in strain was advisable. The decision to retain the A-82 strain signaled a change in policy, and indicates that future decisions will rely heavily on available data which compare the current strain in production with the candidate strain(s).

The aspect of strain evaluation examines changes that have occurred in the current strain during the past year, and whether these changes are indicative of strain "deterioration". Data from rearings of the candidate strain are used to assess how well it is adapting to the colonization procedures. In both instances, we can examine the characteristics and fitness of each strain, using simple life table statistics, to estimate their net reproductive rates (R_0). This memo will propose the use of R_0 to monitor the quality of strains in Production on a continuous basis, and as a standard to assess the adaptability of candidate strains in Methods.

Net reproductive rate is defined as the number of females produced per female per generation. It is derived by multiplying (1) the average fecundity of a female, (2) the sex ratio of the offspring, and (3) the probabilities of surviving each life stage. Additional parameters are included to estimate the propensity of a female to mate and oviposit. An R_0 value of 1 implies a stable population that neither increases nor decreases from generation to generation. A value less than 1 implies that colonization is not feasible, while a value greater than 1 indicates that the population size will increase per generation by a factor equal to the R_0 value. In the case of the strain in Production and in Methods, R_0 obviously will be much greater than 1. The usefulness of R_0 will lie in evaluating and monitoring its parameters. All parameters can be incorporated into a simple mathematical equation:

$R_0 = F \times Ph \times Si \times Pf \times Sa \times PF = \text{no. fem./fem./generation, where}$

F= fecundity at reproductive age,
Ph= proportion of the eggs that hatch,
Si= proportion of immatures that survive larval development,
Pf= proportion of population that is female,
Sa= survival of females to reproductive age, and
PF= proportion of fecundity realized.

The parameter PF can easily be estimated by:

$PF = \frac{\text{grams of eggs deposited}}{\text{expected grams of eggs if all surviving females would oviposit.}}$

Alternatively, PF can be estimated by multiplying the proportion of females that mate by the proportion of the mated females that oviposit.

Most of the measurements needed to compute R_0 are already being made in both Production and Methods Sections. With existing data, I was able to compute R_0 for the A-82 strain in Production, and for the O-83 strain in Methods; I present these data here only as an example of how R_0 is computed, and how

it might be used to trouble shoot or compare strains. The parameters Ph and Si were combined for the A-82 strain. because separate estimates were not readily available. The comparison is presented below.

STRAIN	F	x	Ph	x	Si	x	Pf	x	Sa	x	PF	=	Ro
O-83	220		.90		.55		.5		.85		.27		12.5
A-82	220		1	.54	1		.5		.85		.44		22.2

Although some estimates were used by both Production and Methods (F, Sa), some differences are apparent that have resulted in large differences in the estimates of Ro. The product of Ph and Si is .495 for O-83 and .54 for A-82. This is the result of a higher proportion hatch for A-82 (.97, according to R. Marroquin), and may reflect actual differences between strains, or possibly, differences in the techniques of measuring proportion hatch. The greatest disparity in parameters lies in the proportion of fecundity realized (PF). In both instances, this was estimated using the number of grams of eggs collected per cage divided by the expected number (assuming 100% mating and oviposition). Differences could reflect differences in procedures used by the two Sections. However, differences may reflect the greater adaptation of A-82 to the mass rearing methodologies, and the continuing adaptation of O-83. As a result, adults of A-82 are more likely to mate and oviposit, resulting in a higher proportion of fecundity realized. This could also account for the higher proportion hatch exhibited by the A-82 strain.

Since a new cohort is begun three times each day, new estimates of Ro can be computed for each shift. Any endpoint can be used, but all data must be collected from the same cohort. For example, if we use an egg as the endpoint to estimate proportion fecundity realized (PF), we must 'work backward' to find the proportion of those females that survived to reproductive age (Sa), the proportion that survived larval development (Si), and the proportion that hatched (Ph). In addition, dissections of females at reproductive age must be undertaken in order to accurately estimate the average fecundity.

Trends can be plotted and analyzed by examining estimates of each parameter over time. For example we can plot the average fecundity for the past 30 days. This would involve 30x3=90 data points. A regression equation can be computed and we can test to determine whether the slope of the line (i.e. change in fecundity) differs significantly from 0. If so, the value of the slope will indicate the direction and magnitude of change. To help trouble shoot, significant changes over time can then be correlated with changes in procedures or changes in materials that occurred during that period. Similarly, regression equations for each parameter can be compared month to month or year to year. This technique will also enable us to compare strains parameter by parameter.

I must stress that the examples given in this memo are based on rough estimates and should not be construed as factual. Clearly, methods for collecting data for each parameter must be scrutinized and finely tuned. I would like to spend some time in the plant in both Production and Methods, dissecting gravid females to obtain more accurate estimates of fecundity, and determining the ease with which this project could become an integral part of within-plant quality control. I would also like access to data from previous months and years to test the hypothesis that strain deterioration (or adaptability) can be detected using simple life table statistics to estimate Ro.

PRODUCTION WEEKLY ACTIVITY REPORT 0-83

PRODUCCION SEMANAL DE 0-83

26 de Diciembre de 1983 al 1° de Enero de 1984.

LOMA
LOS:

DE JAULAS UTILIZADAS
NUMBER OF CAGES UTILIZED

41

CANTIDAD TOTAL DE HUEVECILLOS PRODUCIDOS
TOTAL QUANTITY OF EGGS PRODUCED

3,108.0 g.

PROMEDIO POR JAULA
AVERAGE PER CAGE

75.8 g.

ISO:

REAR REARING:

PROMEDIO LARVARIO
AVERAGE LARVAL WEIGHT

71.26 mg.

PRODUCCION DE PUPA
PUPAE PRODUCED

2,618.5 l.

PRODUCCION DE PUPA:
PUPAE PRODUCTION:

FECHA
DATE UTILIZADO EN COLONIA
UTILIZED IN COLONY

IRRADIACION
IRRADIATION

TOT. L
TOT. L

/XII/83

42.0 l.

275.9 l.

317.9 l.

/XII/83

42.0 l.

383.0 l.

425.0 l.

/XII/83

42.0 l.

259.8 l.

301.8 l.

/XII/83

42.0 l.

368.0 l.

410.0 l.

/XII/83

42.0 l.

273.3 l.

315.3 l.

/XII/83

42.0 l.

269.2 l.

311.2 l.

/I/84

42.0 l.

152.8 l.

194.8 l.

TOTAL:

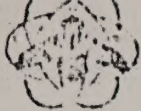
2,276.0 l.

LITROS CONTIENEN
LITERS CONTAINED

22,760,100

PUPAS
PUPAE.

REMARKS: La oviposición por jaula sufrió un descenso debido a un retraso que se presentó en la edad de los adultos.



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO PARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL CAMPESINO

COMISA 2400

OFICE CARRETERA A LA AMISTAD

AIRTEL POSTAL 244

CINCUENTA DE AGOSTO DE 1984

January 10, 1984.

SUBJECT: SPECIAL REPORT, COMMISSION ADMINISTRATION.

TO: SEE DISTRIBUTION.

In Theory Z Robert Ouchi makes the axiomatic observation that managers measure, or at least try to measure, those things in which they are interested. An organization not making such measurements is unable to judge its own effectiveness and therefore unable to determine the changes required for improvement.

The production department (as other departments of the so-called technical disciplines) constantly monitors those factors which indicate our relative conditions in various areas. The information generated such as temperature and humidity at every stage of the fly's life cycle, age of ovipositing adults, egg hatch rate, age at irradiation, time till first emergence, etc. is used in both the short and long range. In the short range it is used to make day to day adjustments to procedures and in directing special attention to particular problems. In the long range it is used to measure overall health and progress of our department by comparing the data from specific periods against similar periods distantly separated. It is this latter comparison which allows us to set goals such as production numbers and larval size and to plan for major alterations like strain changes or number of larval floor groups. The data and its analysis thus serve as standards by which we subsequently measure the success of the changes made in operations and techniques.

The various functions involved in the administration of a multifaceted organization are no less technical than the functions of the Production, Methods Development or Maintenance and Engineering Departments. The monitoring and comparison techniques used by these departments can be used by administrative personnel for the same purpose: effective management of the department.

Factors which could and should be monitored and compared are numerous and varied. No doubt, most of the factors are currently being monitored; they can serve to tell an organization where it stands. What is missing is that essential comparison to determine where the organization should (or wants) to be and the changes necessary to get there. As administration is a common function in all organizations, they have the advantage of having two comparisons at their disposal. First is an internal comparison over time. Second, is the comparison of specific data against comparable

data in other organizations, public or private, or against standards previously set.

A limited list and discussion of the factors which should be monitored and analyzed is presented below:

a. Supply and Inventory.

- How accurate is our inventory?
- Do we repeatedly exhaust the supply of specific items?
- How long does a requisition take to be filled? Are there exceptions?
- What is a tolerable delay in other production industries? How do they manage their system?

b. Absenteeism.

- What is our absentee rate? Per month? per season? Per shift?
- What is the absentee rate in other industries? What is acceptable? How do they control it? How do they prepare for high absentee periods?
- What is the cause of our absentee rate? Do we have more illness than other industries?

c. Personnel Actions.

- How many reports of personnel misconduct are generated per week, month or quarter? How many result in a "hearing" ("acta")? What sanctions are normally issued?
- How do the above data compare with other production industries? Other businesses at large? Other government agencies? Are we too lax or too hard on our personnel?

d. Turnover.

- At what rate do personnel leave the Commission? What causes predominate? Too high a turn-over involves training of new personnel; too low indicates a permissive management not adequately challenging its personnel.
- How do these figures compare with other organizations?

e. Personnel Development.

- How many job related training courses do we offer? How much in advance are these planned so that they can be taken advantage of? What level and type of personnel are included?
- How do these data compare with other organizations?
- What do individuals want in this regard? Will they volunteer some of their own time?

f. Personal Incentives.

- What type of incentive awards program do other organizations use? What rewards do they give? What system is used to select the recipients?

- How many suggestions for improvement of operations are received each month? From whom?
- How does the number of suggestions compare with other government or private organizations?
- Do they have a suggestion program?
- How do they reward the program participants? It is cost effective?
- How long does private industry take to establish guidelines? Our incentive awards program has been under study for months.

The list and questions/comments are not intended to be exhaustive; they should serve as a starting point to analyzing the functions to which they refer.

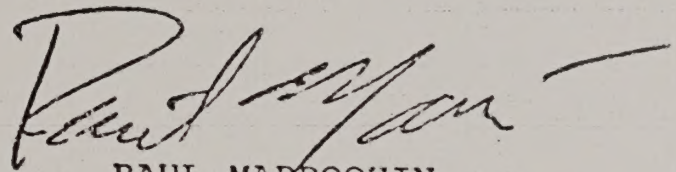
It is common in analyzing production procedures and basic operations to seek outside advice. This has resulted in unbiased assessments and fresh ideas and recommendations. In contrast, it appears that most programs or changes in policy on administrative matters come from one or two individuals. In most cases these are of a "re-active" nature rather than "active", i.e., they are formed as stopgap measures to solve a specific problem rather than a plan to prevent problems or improve ongoing programs. This is indicative of an organization that does not monitor their activities and/or fails to analyze and utilize the data available to it.

As an initial step toward resolving our administrative problems some proposals are presented below.

- a. That administrative sections be required to monitor, compare, report and utilize the available data in order to make appropriate changes in administrative functions.
- b. That the co-director in conjunction with the director (or other appropriate authority) issue instructions now for the next technical meeting to include complete presentations (graphs, tables, etc.) of an administrative nature addressing the above mentioned factors and others which affect management of this commission. This must include internal comparisons over time, comparisons with other organizations or suitable standards and proposals for improvement of the functions.
- c. That personnel from Administration and Management Services be invited to review administrative and management procedures and present subsequent analyses and recommendations to correct deficiencies in the various functions. Further, that these Administration and Management personnel be asked to take part in the sessions of the technical meeting which deal with administrative functions and contribute to the discussions and proposals. Advice from ARS, other

. 4 .

APHIS sections and other qualified personnel has
proven extremely valuable to other departments.



RAUL MARROQUIN
CHIEF OF PRODUCTION

Distribution:

Dr. Floyd Smith
Dr. James Moulthrop
Dr. Robert E. Reichard
Dr. James Novy
Dr. Ronald E. Lowe
File
'gysrg

2 de Enero de 1983.

A: BIOL. RENE GARCIA RODRIGUEZ,
MR. CHARLES MACVEAN,
ENTOMOLOGOS ASISTENTES,
EDIFICIO.

Por este conducto envío a ustedes los resultados obtenidos en forma individual durante la primera semana de muestreo de pupa 0-83 (22 al 28 de Diciembre de 1982), recién irradiada, en el turno B₁!

FECHA DE IRRADIAC.	EDAD	TIEMPO DE EMERG. (HORAS:MINUTOS)	PERIODO DE EMERGENCIA			TOTAL
			24:00	48:00	72:00	
23	6:20	21:00	55.20%	33.00%	0.60%	88.80%
23	6:20	22:50	66.20%	25.80%	0.40%	92.40%
24	6:20	19:00	62.80%	26.00%	0.00%	88.80%
25	6:16	6:40	43.20%	42.80%	2.00%	88.00%
26	6:16	10:00	37.60%	38.60%	10.80%	87.00%
27	6:16	24:30	40.00%	44.40%	3.80%	88.20%
28	6:16	24:00	67.20%	13.20%	6.60%	87.00%
X	6:17:42	18.17	53.17%	31.97%	3.46%	88.60%

Atentamente,

BIOL. ROSARIO CORTES MELENDEZ
Jefe de la Ofna. Control de Calidad.

c.c.p. Archivo.

*alma.

Jan. 13, 1984

Subject: Test of SWASS in Jamaica

To: Mr. W. H. Sudlow-Chief Staff Off. Screwworms APHIS

From: D. E. Hopkins

I understand that a test of SWASS pellets in Jamaica may be considered.

I am interested in SWASS, the product. My concern stems from general interests in methods of executing and reporting tests and in the economical use of resource, from specific interests in anything concerning screwworms, and from keen interests in the integrity of tests in general.

I was not an eye witness when SWASS pellets were first tested in Texas and retested in Colima and Veracruz, but I did follow the reports. I was an on-the-spot observer when, at times, SWASS pellets were applied for practical control in Mexico and retested near Altamirano, Guerrero. In my opinion, based on the evidence presented in reports and on personal observations, SWASS pellets have not yet been positively proven as a practical system for control of screwworms. In comparison, the negative evidence regarding SWASS pellets is more compelling than the positive, and it remains possible that the interpretations of data that seemed to prove that SWASS pellets were effective resulted from circumstances that were somehow biased in their favor.

Much money has been spent these last few years on testing, promoting, manufacturing, storing, shipping, and applying SWASS pellets. If more effort is spent on tests with this current poison-bait system (SWASS-pellet formulation ca. 1978-83) the test should be, out of fairness to those funding the effort, comprehensive and decisive. The public deserves, once and for all, an unmitigated answer.

It is basic to standard techniques of testing that in trials of the application of a chemical for control of an insect that vital data observed concerning a treated population be statistically compared to that observed simultaneously concerning a separate but identical population that remained untreated. In field-tests of screwworms, two like populations properly separated are seldom encountered. But if a definitive test is to be conducted an adequate control (or several replicates of a demonstration) must be provided. If simply a demonstration, whereby SWASS were applied without a reliable control, were made and a dramatic reduction in the population density were monitored it would be convincing, but the question of whether such a reduction would have occurred naturally would remain.

I am submitting, for consideration, two plans for tests on the island of Jamaica; in one, Plan A, periods of time, and in another, Plan B, management of adjacent areas of land provide substitutes for the standard type of control.

As a preface to the Test-Plans there follows a discussion of some theoretical aspects of testing SWASS against a native population of screwworms:

Theoretical Reproduction-Cycles (in Jamaica the
egg-to-adult cycle is probably 13-15 days)
Relative to Presence of SWASS

Given conditions: The average number of wounds available per day (or other given unit of time) is constant. No SWASS is present.

Expected observations: The average numbers of new eggs, larvae, pupae, and egg-laying adults produced per given units of time are constant.

Given conditions: The average number of wounds available per day (or other given unit of time is constant. SWASS is continuously present at the maximum effective strength.

Expected observations: (Typically, swormlure, therefore SWASS, attracts females of about 4 days of age or younger). SWASS would remove (kill) from the recycling-population a large portion of the daily production of new flies (SWASS would not affect the eggs, larvae, pupae, and old flies that were present when it were introduced). However, compared to periods before SWASS were present there would be immediate marked reductions in the population densities of flies, and, once the old flies (4 days of age or older) present when SWASS were introduced began to become too old to reproduce (probably within 3-7 days), there would be gradual reductions in the production of egg masses.

PLAN A

(Use of periods of time to gain effect
of standard-type control)

Step 1 - Place 10 standard wind oriented traps, baited with SWASS pellets, 3 km apart and 3 pens of animals, with infested wounds, 5 km apart in the center of the area of greatest fly activity (judge from reports of cases), and using STRICT, CONSISTANT (important) schedules of replenishing or renewing attractant in traps and of infesting and curing wounds collect pre-treatment data by determining for 10-14 days the average, per specified period of time, frequencies of collections (for future convenience fc = frequencies of collection) of flies and egg masses.

Step 2 - Following the period of collections in Step 1 start the test by treating the entire island with SWASS according to the standard recommendations. Treat for 7 days only. Monitor continuously the fc 's.

Expected results 1st-7th day of test - Once the effects of SWASS reached the maximum (probably in 4-7 days) expect a definite decrease in the fc of flies, compared to that of the pre-treatment period. Expect no reduction in the fc of egg masses (the existing egg-producing population should continue to oviposit).

Expected results 8th-14th day of test - (Note: this period is critical as it is the period of time that serves as control). Expect an increase in the fc of flies as curtailing applications of SWASS should allow the last of the larvae and pupae present when SWASS were first introduced that develop to adults to survive normally. Expect a decrease in the fc of egg masses as SWASS should have removed the adults that would deposit eggs during this period.

Step 3 - Treat island per standard recommendations for days 15-35 of the test.

Expected results 15th-21st day of test - Expect a very low fc of flies, compared to that of the pre-treatment period. Expect a minor increase in the fc of egg masses compared to the period of the 8th-14th day. New adults should develop and survive the 8th-14th day and begin to oviposit.

Expected results 22nd-35th day of test - The fc 's of both flies and egg masses

should be reduced to, and remain, at most, 25%* of those for the pre-treatment period as the density of the recycling-population should be greatly reduced.

PLAN B

(Management of land-areas in lieu of standard-type control)

Step 1 - Place 11 standard wind oriented traps numbered, consecutively, 1-11 and baited with SWASS pellets 3 km apart and 7 pens of animals, with infested wounds, 5 km apart and numbered, consecutively, 1-7 on straight lines with the center trap and pen in the center of the area of greatest fly activity (judge from reports of cases), and using STRICT, CONSISTENT (important) schedules of replenishing or renewing the attractant in traps and of infesting and curing wounds collect pre-treatment data by determining for 10-14 days the average fc's (per specified period of time) of flies and egg masses.

Step 2 - Following the period of collections in Step 1 start the test by treating with SWASS, at the standard recommendations, an area 15 km wide from shore line to shore line that has at the center of its center lateral axis the center trap and pen. Treat for 21 days. Traps #1 & #11, #2 & #10, and #3 & #9 would be, respectively, 7.5, 4.5, and 1.5 km outside the treated area and traps #4 & #8 and #5 & #7 would be, respectively, 1.5 and 4.5 km within the treated area with #6 in the center; pens #1 & #7 and #2 & #6 would be, respectively, 7.5 and 2.5 km outside the treated area, pens #3 & #5 2.5 km within the treated area, and #4 in the center. Monitor continuously the fc's. (Note: Variations of the straight-line orientation could be used, but the distances that were outlined would be critical).

Expected results 1st-7th day of test - Once the effects of SWASS reached the maximum (probably in 4-7 days) expect the fc's of flies in the centermost traps to decrease, compared to those of the pre-treatment period and to those of the outermost traps. Expect the fc's of egg masses to not change appreciably.

Expected results 8th-14th day of test - Expect the fc's of flies in the centermost traps to remain low compared to those of the pre-treatment period and to those in the outermost traps. Expect the fc's of egg masses in the centermost pens to decrease compared to those of the pre-treatment period and to those in the outermost pens.

Expected results 15th-21st day of test - The fc's of flies and egg masses in the centermost traps and pens should be reduced to, and remain, at most, 25%* of those for the pre-treatment period. Note: The areas of land outside the treated areas would serve as control-areas. If SWASS has the desired effect graduated differences in the fc's of flies and egg masses should occur among traps and pens with the highest fc's occurring in the outermost.

*Any significant difference between the fc's for the pre-treatment and treatment periods or among the fc's in the centermost and outermost traps and pens would indicate an effect, and the criterion of 25% is only arbitrary. For very dense populations any reduction would, theoretically, be more pronounced than for any sparser population.

It is a bit unsettling that, after all the time and money spent on SWASS, we do not un-

derstand it better. Perhaps the next test will result in some definitive answers.

Besides the test of SWASS, the feasibility of treating infested areas by ground-release of sterile flies (a follow-up of the work by Dr. R. J. Erenner in the Tapchula area) could be tested in Jamacia. Shipping, by common carrier, chilled sterile pupae from Tuxtla to Jamacia and dispersing them by ground-vehicle would be the most economical and perhaps the most reliable way to disperse. The ground-release method is promising enough to warrant a thorough testing and the treatment of Jamacia would offer an excellent opportunity.

D. E. Hopkins
D. E. Hopkins
811 Lake Dr.
Kerrville Texas 78028

cc:

R. A. Bram

O. H. Graham

J. W. Mackley



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

January 19, 1984

SUBJECT: Transmittal of Manuscript for
Areas Director's Approval

TO: J. R. Johnston

To save time in the mail, I am sending 4 copies of a manuscript by R. J. Brenner and D. E. Hopkins, "Dispersal, Mating, and Oviposition of the Screwworm (Diptera: Calliphoridae) in Southern Mexico" direct to your office even though ARS-115 is not included. By copy of this memo I am asking Josie Salinas at Weslaco to prepare the ARS-115 and formal cover letter, sign them for me, and send them to you. I do recommend approval of the manuscript for publication.

I apologize for this irregularity. We are taking steps to obtain a supply of Form ARS-115.

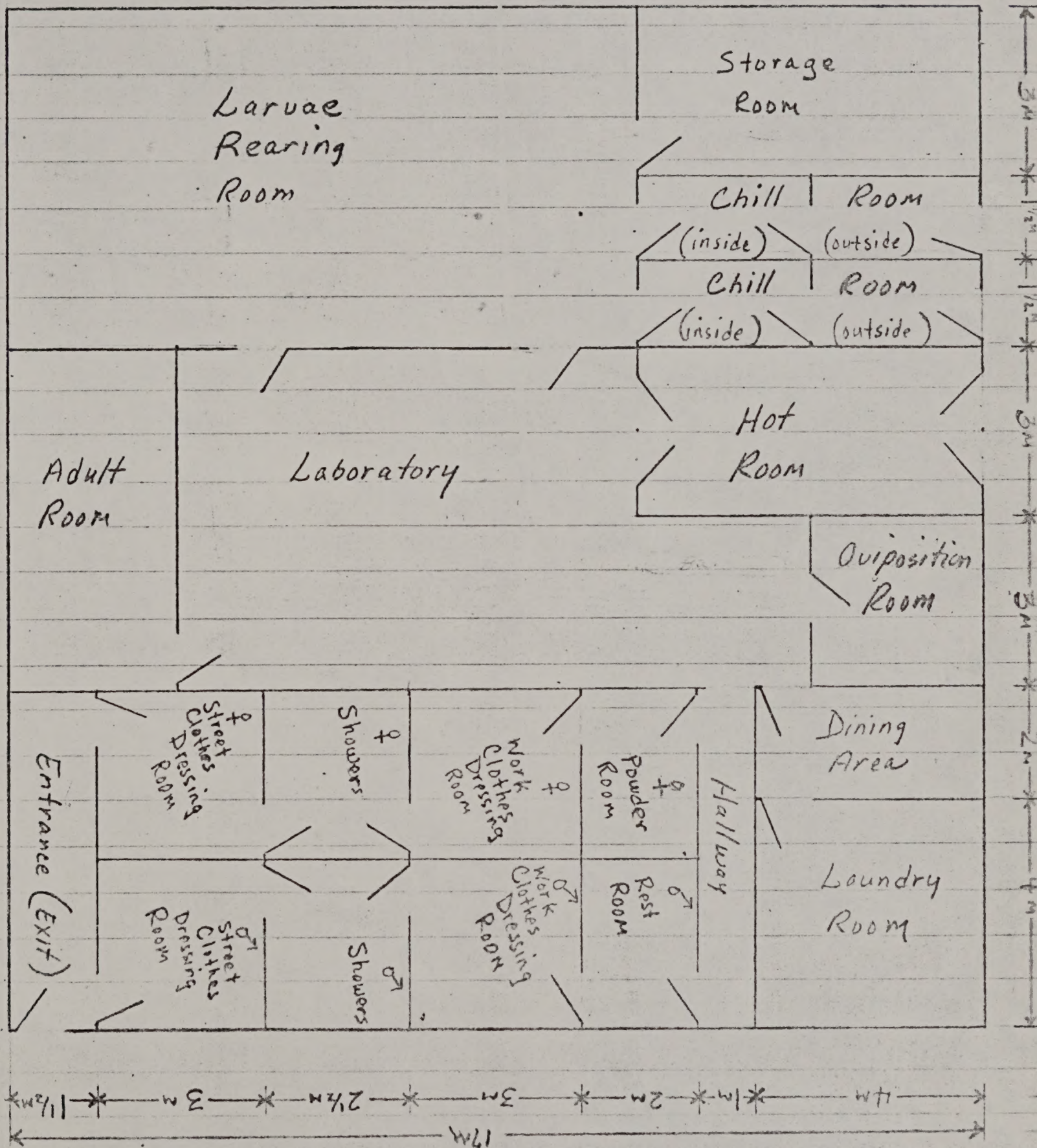
O. H. GRAHAM
Location/Project Leader

cc:

Josie Salinas
R. J. Brenner
D. E. Hopkins

Hugh
For your information
new design for strain
development building

Plan for strain
development laboratory
01/25/84





United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

January 30, 1984

SUBJECT: Research Resumes for Scientist in
Screwworm Research

TO: R. A. Bram

Per your telephone request I am sending resumen of current assignments, accomplishments, and goals for the 7 scientists in Tuxtla Gutierrez and for Dr. R. L. Harris who is devoting 0.2 of his time to screwworm research. Dr. H. E. Brown is mailing a resume to you.

O. H. GRAHAM
Location Leader

cc:

J. R. Johnston, w/enclosures
H. E. Brown, w/enclosures

1. Project: Screwworm Research

2. Scientist: James W. Mackley
Research Entomologist
Tuxtla Gutierrez, Chiapas
FY 1984 - 1.05 SY
FY 1979-83 - 5.0 SY

3. Current Research:

Enhance the attractiveness of swormlure under tropical conditions. Find new, more effective attractants.

4. Accomplishments:

Leader of a team which developed swormlure-4. Defined some of the conditions which influence the effectiveness of SWASS.

5. Research Goals:

Improvise an entirely new attractant - feeding bait - toxicant combination for use along southern edge of Tehuantepec sterile fly barrier and test the new product in the Caribbean and Central America.

1. Project: Screwworm Research
2. Scientist: Richard D. Peterson II
Research Entomologist
Tuxtla Gutierrez, Chiapas
FY 1984 - 1.0 SY
FY 1979-83 - 5.0 SY
3. Current Research:
New control measures to supplement sterile fly release; improved survey techniques.
4. Accomplishments:
Revealed influence of trap color and wind movement on trapping success under Texas conditions.
5. Research Goals:
Development of a mini-trap that can be used in large numbers in remote areas of Mexico as both a survey tool and a control device.

1. Project: Screwworm Research

2. Scientist: Richard J. Brenner
Research Entomologist
Tuxtla Gutierrez, Chiapas
FY 1984 - 1.0 SY
FY 1983 - 1.0 SY

3. Current Research:
Influence of tropical habitats on screwworm behavior and reproductive potential; other aspects of screwworm ecology.

4. Accomplishments:
Related fly movements to host animal concentrations, vegetation, water, and air movement.

5. Research Goals:
Develop a semen marker for use in simultaneous testing of two or more strains of screwworms for male mating effectiveness in the field.

1. Project: Screwworm Research
2. Scientist: Robert L. Mangan
Research Entomologist
Tuxtla Gutierrez, Chiapas
FY 1984 - 1.0 SY
FY 1983 - 0.6 SY
3. Current Research:
The genetic component of factory adaptation of screwworm strains; mating behavior in nature.
4. Accomplishments:
Found that host animal and wound type do not exert sufficient influence on the genetic process to produce new species or reproductively isolated types of screwworms.
5. Research Goals:
Determine why some new laboratory strains are better fitted for mass production and use in a sterile insect release program than other strains.

1. Project: Screwworm Research
2. Scientist: William L. Rubink
Research Entomologist
Tuxtla Gutierrez, Chiapas
FY 1984 - 1.0 SY
FY 1983 - 0.6 SY
3. Current Research:
Basic biology and reproductive potential of the screwworm in the tropics;
biological control mechanisms.
4. Accomplishments:
Compared the influence of several pupation media and moisture conditions
on pupation success.
5. Research Goals:
Study the life history of the screwworm outdoors in the tropics and
elucidate the factors which influence its reproductive potential.

1. Project: Screwworm Research

2. Scientist: Robert L. Harris
Research Entomologist
College Station, Texas 77841
FY 1983 - 0.2 SY
FY 1984 - 0.2 SY

3. Current Research:
Improved larval diets for screwworms; improvements in rearing technology to reduce costs.

4. Accomplishments:
Two gelling agents, SGP-147 and Norbak, were used to solidify liquid diets and eliminate fibrous substrates.

5. Research Goals:
To carry most promising developments in the laboratory to the mass production rearing plant and make the modifications needed to insure their successful use to rear 600 million sterile flies per week at substantial saving in cost.

1. Project: Screwworm Research

2. Scientist: Owen H. Graham
Supervisory Entomologist
Tuxtla Gutierrez, Chiapas
FY 1984 - 1.0 SY
FY 1980-83 - 3.2 SY

3. Current Research:
New methods of treating screwworm infested livestock and their application to cattle transported across quarantine lines.

4. Accomplishments:
Studied the epidemiology of reinfestations that appear in zones freed of screwworms.

5. Research Goals:
Provide control technology that can be used to facilitate the transport of almost 1,000,000 cattle per year from screwworm infested zones of Mexico to screwworm-free areas.

1. Project: Screwworm Research

2. Scientist: David B. Taylor
Research Geneticist (Insects)
Tuxtla Gutierrez, Chiapas
FY 1984 - 1.0 SY
FY 1983 - 0.7 SY

3. Current Research:
Improved techniques for collecting and colonizing new strains of screwworms.

4. Accomplishments:
Developed a technique for forced crossing of newly colonized lines to give a broader genetic base yet save time.

5. Research Goals:
Classic genetic studies of the screwworm; prepare linkage maps based on enzymatic and morphological characteristics; develop electrophoretic systems; study population genetics.



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

January 30, 1984

SUBJECT: Research Resumes for Scientist in
Screwworm Research

TO: R. A. Bram

Per your telephone request I am sending resumen of current assignments, accomplishments, and goals for the 7 scientists in Tuxtla Gutierrez and for Dr. R. L. Harris who is devoting 0.2 of his time to screwworm research. Dr. H. E. Brown is mailing a resume to you.

O. H. GRAHAM
Location Leader

cc:

J. R. Johnston, w/enclosures
H. E. Brown, w/enclosures

1. Project: Screwworm Research

2. Scientist: James W. Mackley
Research Entomologist
Tuxtla Gutierrez, Chiapas
FY 1984 - 1.05 SY
FY 1979-83 - 5.0 SY

3. Current Research:

Enhance the attractiveness of swormlure under tropical conditions. Find new, more effective attractants.

4. Accomplishments:

Leader of a team which developed swormlure-4. Defined some of the conditions which influence the effectiveness of SWASS.

5. Research Goals:

Improvise an entirely new attractant - feeding bait - toxicant combination for use along southern edge of Tehuantepec sterile fly barrier and test the new product in the Caribbean and Central America.

1. Project: Screwworm Research
2. Scientist: Richard D. Peterson II
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Tuxtla Gutierrez, Chiapas
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FY 1983 - 1.0 SY

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Influence of tropical habitats on screwworm behavior and reproductive potential; other aspects of screwworm ecology.

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United States
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Agricultural
Research
Service

Southern Region
Southern Plains Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

Feb. 6, 1984

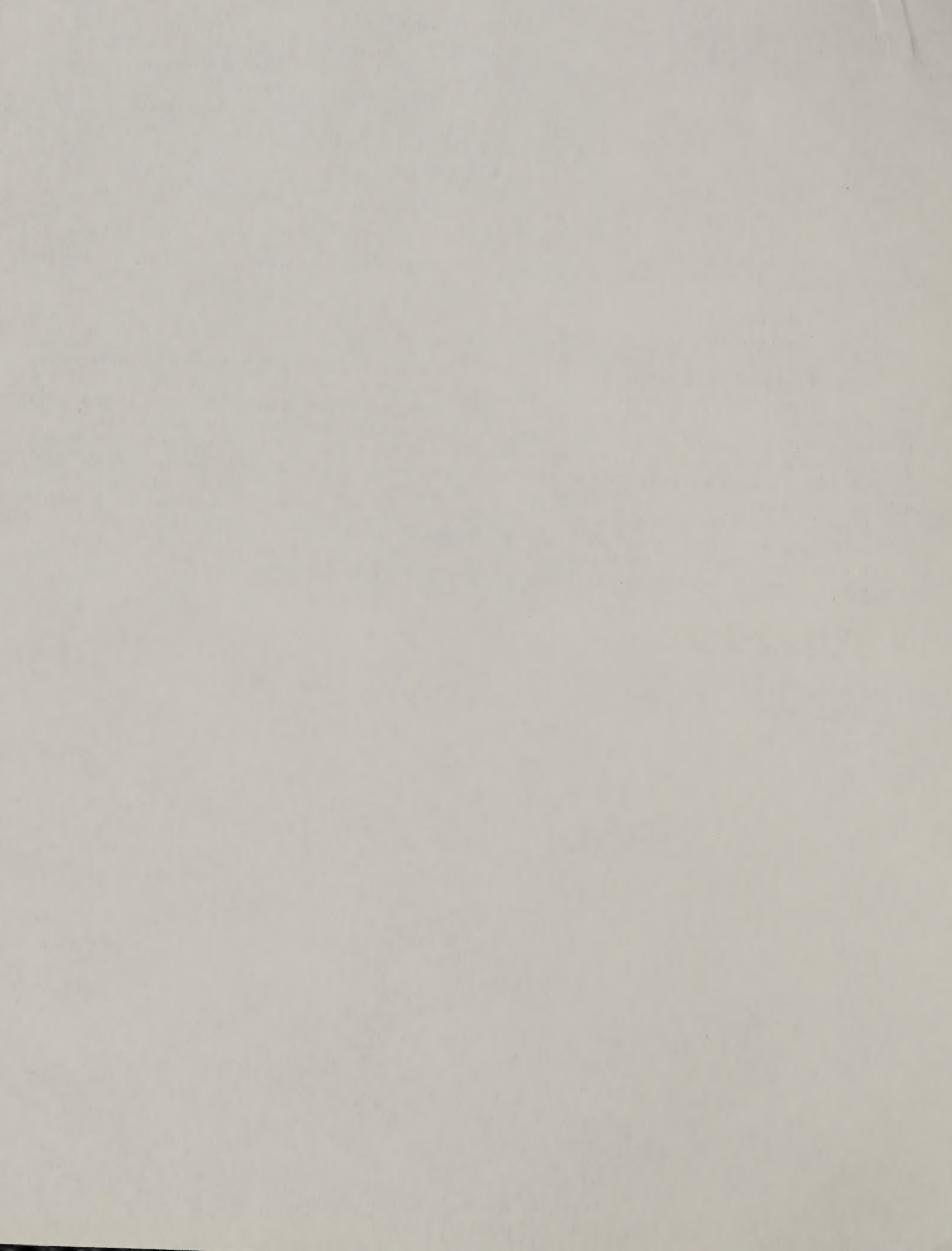
Subject: Proposal to test plastic mesh mats in the Methods Development Section.

To: Dr. J. D. Hoffman
Dr. Arturo Martinez y Tapia

As I mentioned this morning, Bob Harris and Allen Miller have not been able to rear larvae of an acceptable size in their current tests of two plastic mesh mats. We feel that the small size, approx. 55 mg, may be caused more by their working conditions than by any inherent characteristics of the mats. Even though we have not been able to demonstrate it we continue to believe that a rearing technique can be developed by which the test mats and the standard factory rearing medium can be used to at least equal what is now being done with the acetate.

I will therefore appreciate your consideration of the enclosed protocol for a jointly conducted test in your rearing facility where you routinely provide around the clock care of the larvae and have vacuum heads available. This protocol can probably be improved and we would appreciate receiving any input you might care to provide.

O. H. Graham
Research Leader





United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

Feb. 6, 1984

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O. H. Graham
Research Leader

REFERENCE SLIP

Feb. 7, 1984

TO

Dave Hoffman

- | | |
|--|---|
| ☐ ACTION | ☐ NOTE AND RETURN |
| ☐ APPROVAL | ☐ PER PHONE CALL |
| ☐ AS REQUESTED | ☐ RECOMMENDATION |
| ☐ FOR COMMENT | ☐ REPLY FOR SIGNATURE OF |
| ☐ FOR INFORMATION | ☐ RETURNED |
| ☐ INITIALS | ☐ SEE ME |
| ☐ NOTE AND FILE | ☐ YOUR SIGNATURE |

REMARKS As I read this protocol this

morning, I see several omissions. For example, ~~perhaps we should have stated~~ that the diet, the vacuuming procedures and all the other aspects of the rearing will be your standard procedures. ~~Our offer to furnish gutters etc and help with conduct of the test is just that an offer. We realize that you may prefer to provide everything with out any help from ARS.~~

Can we regard this as merely a first draft of the protocol which we can jointly revise with the help of your input?

FROM

Hugh



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL CANADERO

COMTA 24363

KM. 2 CARRETERA A LA ANGOSTURA
CHIAPA DE CORZO, CHIS.

APDO. POSTAL 544

Febrero 7, 1984

Ref: PGD*062

A: DR. HUGH GRAHAM
Director, Laboratorio
De Investigación del
Gusano Barrenador-ARS.

To: DR. HUGH GRAHAM
Director, ARS Screwworm Research
Laboratory.

Asunto: Pruebas de la malla de plástico.

Subject: Proposed plastic mesh mat tests.

La presente es en respuesta a su memorándum del 6 de Febrero de 1984.

This memo is in response to your memo of February 6, 1984.

Estamos muy impresionados con los atributos potenciales de la malla plástica y creemos que vale la pena seguir investigándola.

We are very impressed with the potential attributes of the plastic mat mesh concept, and feel it is well worth pursuing.

Hemos discutido su memorándum con nuestro personal y deseamos proponer lo siguiente:

We have discussed your memo with our staff and wish to propose:

ARS proporcionará a este Departamento, malla de plástico que tienen disponible (que se ajusta a la charola de Producción tipo standard de 3 x 5 pies).

ARS provide available plastic mesh mats (to fit the standard 3 x 5 foot production vat) to this department.

Nosotros dirigiremos estas pruebas para comparar:

This department will conduct tests to compare:

- Índice de desarrollo.
- Talla larvaria y,
- Producción.

- Rate of development.
- Larval size, and
- Yield.

en malla de plástico y en acetato.

on both plastic mesh and on acetate.

También se tabularán y se analizarán los datos y se hará el reporte.

This department will tabulate and analyze the data and write a report.

Una copia de este reporte se enviará al Dr. Hugh Graham.

A copy of this report to be sent to Dr. Hugh Graham.

El protocolo que se use será de acuerdo al formato incluído en su memorándum.

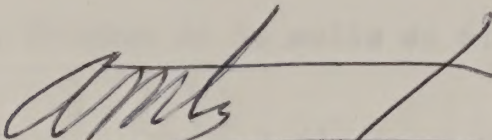
The protocol to be used will essentially follow the format of the one enclosed with your memo.

Pág. No. 2
Ref: PGD*062

February 7, 1963
Ref: PGD*062

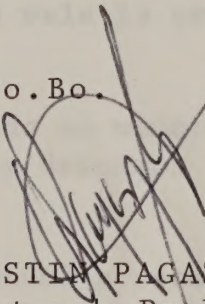
Hacemos una invitación a ARS a inspec-
cionar el progreso de la prueba, y de
que se nos comunique de las observacio-
nes hechas a la misma, a nuestro nivel.

A t e n t a m e n t e .



DR. ARTURO MARTINEZ Y TAPIA
Jefe del Depto. de Investigación
y Desarrollo Experimental.

Vo.Bo.

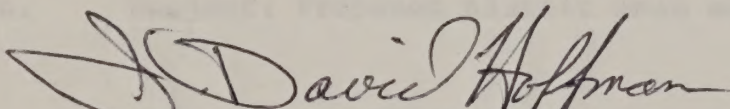


DR. AGUSTIN PAGAZA GARZA
Sub*Director de Producción.

c.c.p. Entomólogos Asistentes.
c.c.p. Jefe de la Ofna. de Pbas. de la Planta.
c.c.p. Archivo.

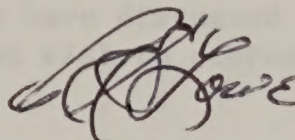
We invite ARS to inspect the test in pro-
gress, but request advice/discussions about
the test procedures be transmitted at our
level.

S i n c e r e l y ,



DR. J. DAVID HOFFMAN
Ch., of Research and Exp.
Development Department.

Vo.Bo.



DR. RONALD E. LOWE
Sub*Director of Production.



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL CANADENO

COMTA 24363

— RM. 2 CALPETERA A LA ANGOSTURA
CHUAPA DE COEZO, CHIS.

APTO. 10574144

Febrero 7, 1984
Ref: PGD*062

A: DR. HUGH GRAHAM
Director, Laboratorio
De Investigación del
Gusano Barrenador-ARS.

To: DR. HUGH GRAHAM
Director, ARS Screwworm Research
Laboratory.

Asunto: Pruebas de la malla de plástico.

Subject: Proposed plastic mesh mat tests.

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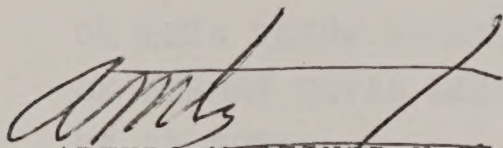
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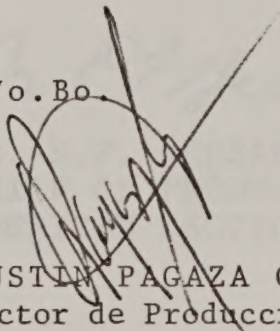
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A t e n t a m e n t e .



DR. ARTURO MARTÍNEZ Y TAPIA
Jefe del Depto. de Investigación
y Desarrollo Experimental.

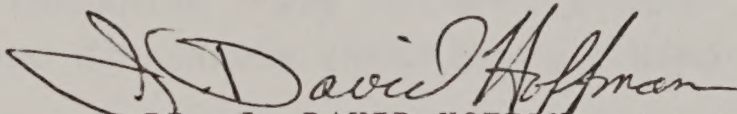
Vo.Bo.



DR. AGUSTÍN PAGAZA GARZA
Sub*Director de Producción.

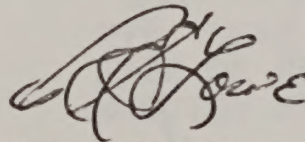
We invite ARS to inspect the test in progress, but request advice/discussions about the test procedures be transmitted at our level.

S i n c e r e l y ,



DR. J. DAVID HOFFMAN
Ch., of Research and Exp.
Development Department.

Vo.Bo.



DR. RONALD E. LOWE
Sub*Director of Production.

c.c.p. Entomólogos Asistentes.
c.c.p. Jefe de la Ofna. de Pbas. de la Planta.
c.c.p. Archivo.



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

COMTA. 24363

KM. 2 CARRETERA A LA ANGOSTURA

APDO. POSTAL 544

CHIAPA DE CORZO, CHIS.

9 de Febrero de 1984.

DR. HUGH GRAHAM
DIRECTOR DE A.R.S.

RECEIVED FEB 13 1984

POR MEDIO DE LA PRESENTE, LES COMUNICAMOS QUE A PARTIR DE ESTA FECHA NECESITAN PRESENTAR TODAS LAS SOLICITUDES DE FORMAS VIVAS DEL GUSANO BARRENADOR ANTES DE UN MINIMO DE 24 HORAS.

A T E N T A M E N T E ,

DR. E.F. GERSABECK
CHIEF OF PRODUCTION, ACTING
AMERICAN SECTION

MVE. LUIS HERNANDEZ
JEFE DE PRODUCCION
SECCION MEXICANA.

C.c.p.- Archivo

Dr. Graham,

One copy given to each Scientists for them to take note.

02/13/84



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

February 13, 1984

SUBJECT: Egg mass deposited on an
artificial wound

TO: Dr. J. D. Hoffman

This will be a very brief report, asked for by your office, about the deposition of an egg mass from a native female on an artificial wound.

There are currently about 30 calves penned on the Plant-grounds. Chemical treatments for screwworms are being investigated and at present 20 of the calves have wounds infested 10-II-84. During the past week or so about 1 or 2 egg masses per day were collected from infested wounds (about 50% were fertile).

An artificial wound (a w) was made by filling a disposable plastic drinking glass about 2/3 full of acetate soaked with diet and infested with about 200 screwworm larvae which were 48 hours old 10-II-84. A piece of cardboard (part of a filing card) about 2 x 4 cm was placed along the side of the glass in contact with the diet surface. The glass was placed in the mouth of a thermos jug filled with warm water in the mornings and evenings. The a w was placed in shade near the pens of calves on the 11th and 12th of February. The diet was not changed, but on the 12th about 10 g of fresh meat was added, and the larvae appeared to feed on it.

On the 12th between 1130 and 2100 hrs an egg mass was deposited on the section of cardboard in the a w. The mass was observed by me, D. E. Hopkins, and Dr. J. D. Hoffman. Unfortunately the action of the larvae destroyed the mass which was left in place in the a w so that a picture might be taken when morning came; one mass was also collected from one of the wounds in the evening of 12-II-84.

D. E. Hopkins
D. E. HOPKINS

Per request of Methods:

Copy to OAG.
02/15/84

PROTOCOL FOR THE COLLECTION OF DATA FOR LIFE
TABLE STATISTICS (O-83 STRAIN)

R. J. Brenner

Formula for Ro (net reproductive rate):

$$Ro = F \times Ph \times Si \times Pf \times Sa \times PF = \text{no. females/female/generation.}$$

<u>PARAMETER</u>	<u>DEFINITION</u>	<u>PROCEDURE</u>
F	Fecundity	Dissect 30 females (min. 10 x 3 reps) prior to placement in oviposition.
Ph	Proportion of hatch	Use data from record books.
Si	Survival of immatures	$\frac{\text{Yield (l)} \times \# \text{ flies/l}}{\text{gms. of eggs} \times 22,000 \text{ eggs/gm}}$
Pf	Sex ratio	Presume 0.50.
Sa	Survival of females to reproductive age	Estimate mortality; remove all dead flies from cage (?).
PF	Proportion of fecundity realized	1. # grams eggs deposited/exp. # 2. % of females <u>not</u> ovipositing a. Post-oviposition: dissect 50 females (min.) and score for 1) parity 2) mating status 3) ovarian stage.

Biological materials needed

1. A minimum of 30 females from pre-oviposition. Ideally, removed just before the cage goes into oviposition.
2. All dead flies from same cage.
3. A minimum of 50 females from the same cage after oviposition.

Work crew

I propose to bring 3 ARS technicians into the plant in order to train them to take these samples properly.



United States
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Southern Region
Southern Plains Area

SCREWORM RESEARCH
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

February 17, 1984

SUBJECT: Report of a Screwworm egg mass deposited
on an artificial wound

TO: Dr. O. H. Graham

An artificial wound (aw) was made by filling a disposable plastic drinking cup (cap. ca. 500 ml.) about 2/3 full of acetate soaked with fresh diet and infested with about 200 screwworm larvae which were 48 hours old 10-II-84. A piece of cardboard (part of a filing card) about 2 x 4 cm was placed standing on end along the side of the cup in contact with the surface of the diet. The cup was placed in the mouth of a thermos jug filled with warm water in the mornings and evenings (see drawing attachment). On the 11th and 12th of February the aw was placed in shade near pens of calves on the Plant-grounds. There are currently about 30 such calves. Chemical treatments for screwworms are being investigated and at present 20 calves have wounds that were infested 10-II-84. During the past week 1 or 2 screwworm egg masses per day were collected from the infested wounds.

The original diet was never replaced. However, about 10 g of fresh horsemeat was added to the aw the morning of the 12th and the larvae appeared to feed on it.

On the 12th between 1130 and 2100 hrs (the water in the jug was not changed in the evening of the 12th) a screwworm egg mass was deposited on the cardboard in the aw. The mass was observed by me, D. E. Hopkins, and by Dr. J. D. Hoffman. Unfortunately the action of the larvae destroyed the mass which was left in place in the aw so that a picture might be taken when morning came. One mass was also collected from a wound on a calf in the evening of 12-II-84.

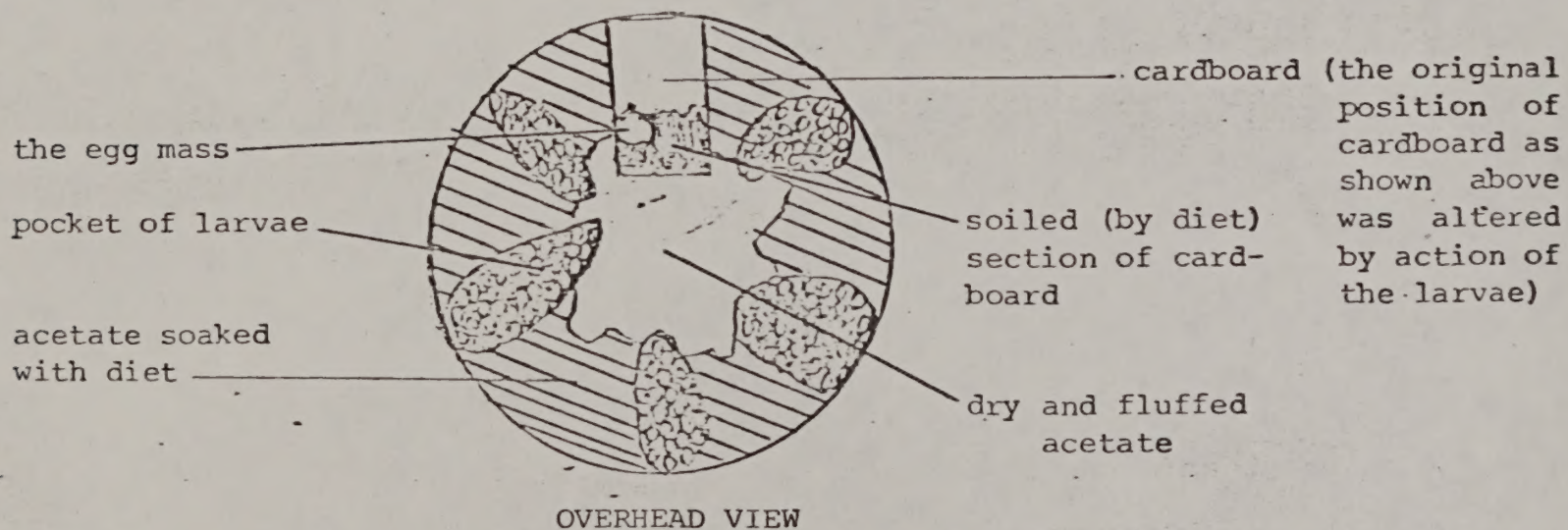
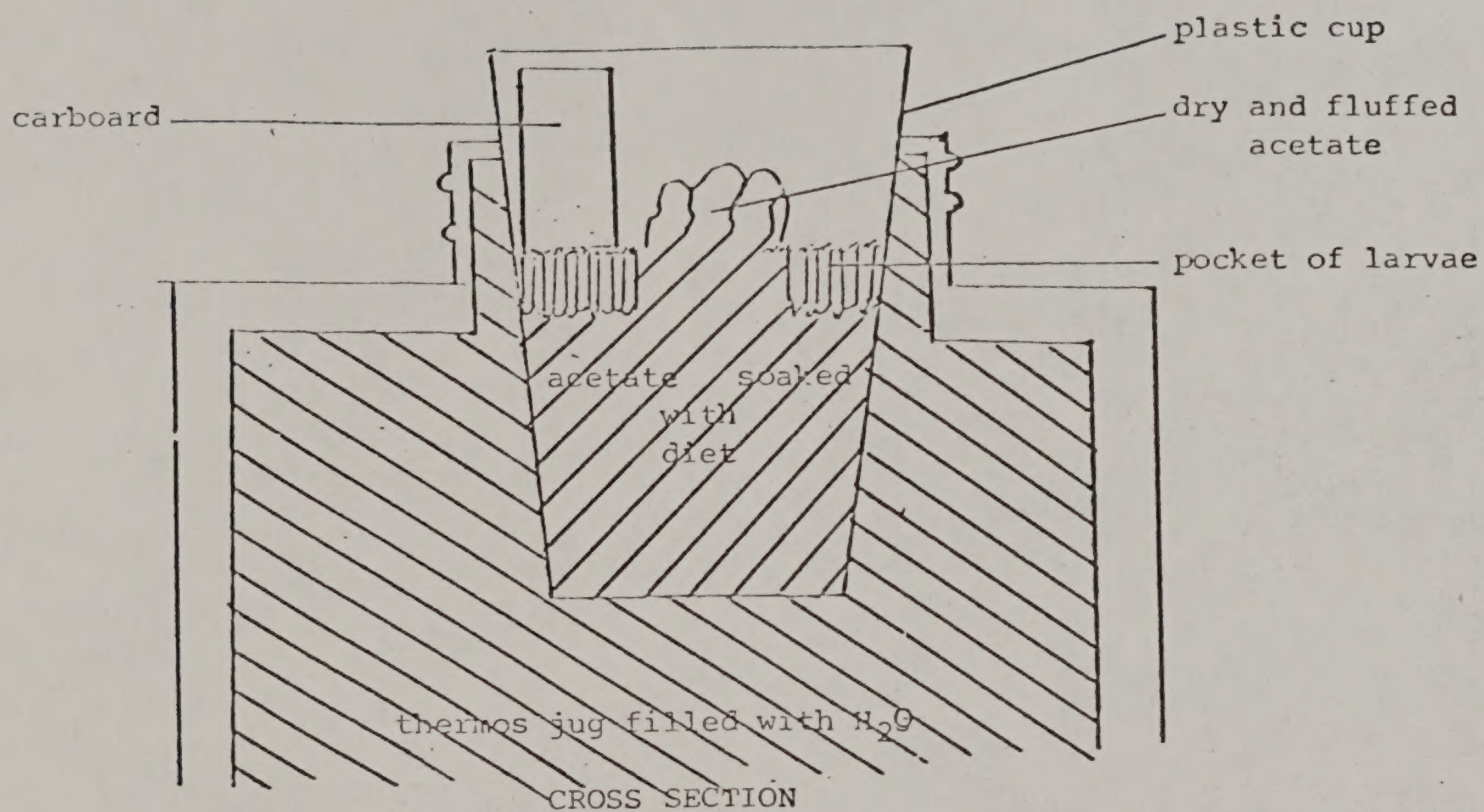
I wish to add some general comments about screwworm attractants.

It is possible that screwworm flies are generally attracted to host animals over relatively long distances and that wounds (i.e., ovipositional sites attract gravid females from distances of only a few feet or perhaps only a few inches.

It is also possible that new wounds are as attractive as older infested wounds. However, uninfested wounds do not remain fresh as they immediately begin to heal. In infested wounds the healing process is in a relative state of equilibrium which could be one of the principle reasons they are continuously attractive.

D. E. Hopkins
D. E. Hopkins

cc: Dr. J. D. Hoffman
Dr. J. B. Welch
Dr. C. J. Whitten
Dr. R. C. Bushland
Dr. R. L. Harris



DIAGRAMATIC SKETCH OF AN ARTIFICIAL WOUND MOUNTED IN A THERMOS JUG OF WATER
Scale (about 1/2)



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

23 de febrero de 1984.

SE PROPONE EL SIGUIENTE PROGRAMA PARA LA PROXIMA JUNTA REFERENTE A LA CEPA. PARA EL 6 DE MARZO DE 1984 EN TUXTLA GUTIERREZ, CHIS. A LAS 10:30 A. M.

Objetivos - Dr. Nazario Pineda - Dr. Robert E. Reichard

- 1.- Cambio de producción de Cepa
- 2.- Cambio de la Oaxaca (0-83) por la de Villa Flores.
- 3.- Continuación con la A-82 en producción, y la 0-83 en Desarrollo de Métodos.

Realización de la Cepa A-82 durante los pasados tres meses (resultados de campo, control de calidad, crianza, etc.), con los comentarios de las siguientes personas:

Dr. Sergio Martínez/Dr. Chris H. Hofmann
Dr. Martínez y Tapia/Dr. Dave Hoffman
Dr. Moisés Vargas
Dr. Luis Hernández/Dr. Ed. Gersabeck

Deterioro de la A-82 a tratar por el,

Dr. Hugh Graham y su equipo.

Realización de la 0-83 (resultados de campo, control de calidad, crianza) con los comentarios de las siguientes personas.

Dr. Sergio Martínez/Dr. Chris H. Hofmann
Dr. Martínez y Tapia/Dr. Dave Hoffman
Dr. Moisés Vargas.

Deterioro de la 0-83 a tratar por el,

Dr. Hugh Graham y su equipo

Presentación de la Cepa Villa Fores por el,

Dr. Hugh Graham y su equipo

Pláticas sobre alternativas y conclusiones por los Drs.



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

- 2 -

Dr. Nazario Pineda/Dr. Robert E. Reichard

Planes futuros a tratar por las siguientes personas,

Dr. Hugh Graham y su equipo

Dr. Nazario Pineda/Dr. Robert E. Reichard y su equipo.



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

0416
Screwworm Research Lab
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

March 2, 1984

Dr. Dennis R. Ring
Dept. of Entomology
Texas A&M University
College Station, TX 77843

Dear Dennis:

After a rather exhaustive study of the most recent version of your paper on the biology and genetics of Chrysomya rufifacies, I have concluded that it is not ready for publication. My reasons will be apparent when you have read the enclosed copy of my review and the notes that I made on the manuscript itself as I read it.

It is still possible to write a publishable report of your findings. If you decide to go ahead with publication I urge that you rewrite the manuscript quickly because it will not be acceptable to any refereed journal if other workers submit a similar report before yours is received.

Sincerely,

Hugh

O. H. GRAHAM
Location Leader

cc:

D. O. McInnis

*copy w/enclosures
in mss. file,
Ring & McInnis*



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

Marzo 2, 1984

Recibí de ARS y llevaré de la Planta a Mérida, Yucatán, 10 borregos para uso de la Sección de Desarrollo de Métodos.

Los números de aretes de los borregos son los siguientes:

580 - macho
540 - hembra
522 - hembra
531 - macho
~~563 - hembra~~
570 - hembra

597 - hembra
579 - hembra
521 - macho
~~574 - macho~~
533 - hembra
~~524 - hembra~~
574 - hembra

P.A.

M.V.Z. RAUL SELVAS ALVAREZ



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

*Complete letter in
folder - strain change*

Screwworm Research Lab
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

March 9, 1984

SUBJECT: Development of New Screwworm
Strains - Plans and Policies

TO: R. A. Bram

As you know, the latest strain of screwworms developed by ARS for use in mass production by the Joint Commission, Villa Flores (VF-84), has been ready for transfer to the Methods Development area of the rearing plant since late February. The Directors called a meeting, which was held in Tuxtla March 6-7, to review the biological characteristics, field performance, and other traits of the three strains now on hand and to decide whether:

- (1) to replace A-82 with O-83 in mass production and place VF-84 in production in Methods, or
- (2) to leave A-82 in mass production but replace O-83 with VF-84 in Methods, or
- (3) not to accept VF-84 and leave all strains in their present locations.

After all pertinent data from Quality Control, Field Operations, and ARS had been reviewed everyone in the group concurred that there is no evidence that A-82 has deteriorated during the approximately 16 months it has been in mass production. In the field it has been, and continues to be, one of the most successful in the history of the program. The Quality Control data also support the conclusion that A-82 has not deteriorated. The only known reasons to worry about the future of this strain are the traits which indicate steadily increasing factory adaptation: (1) high egg production, (2) decreased larval development time, (3) more uniform larval weights, (4) shorter pupation period, (5) compressed adult eclosion period, (6) higher percent adult emergence, and (7) more rapid female maturation (earlier oviposition). Traditionally these, and other similar traits, have preceded declines in effectiveness in the field.

The consensus was that A-82 should remain in mass production, but that further factory adaptation would be cause for replacing it. The opinion of several was that if A-82 deteriorates it will probably do so gradually, not suddenly, and that there will be an opportunity to replace it before a disaster could occur in the field.

Whether or not to replace O-83 with VF-84 was a more complex decision. To judge by most of its characteristics, egg production, larval size, yield, and performance in a field test, O-83 is a highly acceptable strain (see enclosed tabular data from Methods Development). The most obvious negative characteristic of O-83 has been its consistently low adult emergence (see Fig. 5), usually about 10% lower than A-82. Because of the construction work that has gone on in Methods during the entire time O-83 has been reared in that area, it has been suggested that the lower emergence was caused by trauma in the larval collection process or other mechanical rearing problems. However, the data shown in Fig. 9 do not support the idea that

R. A. Bram

trauma in collection has adversely affected adult emergence as the percent emergence for larvae collected from trays was 82.97 in comparison with 83.93 for those collected from the floor.

Some quality control data from distribution centers, principally Tampico and Guadalajara, were even less favorable to O-83. I do not have those data in front of me at this time but, in general, the percentage of useful flies was about 20% lower for O-83 than for A-82. In some cases the percentage of useful O-83 was below 60.

In our laboratory, in tests conducted by Maria Elena Vázquez soon after O-83 was placed in large scale production, the emergence of O-83 was about 5% lower than A-82. In addition she observed O-83 to be more cold sensitive and more heat sensitive than A-82. (See enclosed Fig. 14, 15 & 16).

Naturally much less data is available about VF-84 than the other two strains. At meetings of this kind APHIS officials always want the same kinds of quality control statistics for the new strain as for the mass production strains but those data are never available and never will be unless the new strain is reared a number of generations under the same conditions as the production strain, in which case the "new" strain would no longer be new. Dr. David Taylor presented the information about VF-84 obtained so far (see enclosure). All the indicators are that VF-84 is a vigorous strain that can be mass reared. F_5 larval weights averaged 75 mg. Egg production, egg hatch, pupal yield (ml pupae/mg eggs), and adult emergence data are all quite high for a newly colonized strain.

In spite of its intangible nature, the very newness of the VF-84 strain is in its favor. O-83 has been in culture for about 15 generations longer than VF-84 and for at least part of those 15 generations O-83 was severely stressed by adverse rearing conditions.

After considerable discussion, and after hearing recommendations for and against replacing O-83 with VF-84 in the strain change facility operated by Methods, Commission officials conditionally decided to accept VF-84. The conditions which might cause them to reverse this decision were (1) if an in-depth analysis of all the available data, to be completed in one week, justifies the conclusion that O-83 would be acceptable as a replacement for A-82 in mass production and (2) if Dr. Taylor finds that percent adult emergence for O-83 and A-82 are about the same when they are reared side-by-side in the ARS laboratory. In the meantime both ARS and Methods are preparing to begin the transfer of VF-84 beginning about March 26 (see enclosed copy of memo to Pagaza and Lowe).

The meeting stimulated thoughtful attention to some of the problems of strain development and strain change but not surprisingly left a number of important unanswered questions. I propose that a special effort be made to address the entire subject of future strain changes when we have our Research-Methods Development meeting on May 17 and to answer questions such as the following:

R. A. Bram

(1) Who will develop new strains in the years ahead? In 1985? In the 5 year period, 1985-1989? ARS, or Methods, or some other group?

When considering this and other questions, we must think about at least 3 possibilities: (a) the Joint Commission may eliminate screwworms to Tehuantepec, launch the planned barrier, and maintain it in perpetuity, (b) some disaster may occur and screwworms will move north, or (c) after eradication to Tehuantepec the eradication program may move on into Central America and the Caribbean and eventually a barrier will be established in the Darien.

(2) Where will future new strains come from and where will the laboratory work be done to develop field collected lines into a strain suitable for mass production?

At this time we do not know where we might be able to obtain the next strain, much less the next 5 or 10 strains. If VF-84 for whatever reason cannot be placed into mass production later this year and there were an urgent need to develop a newer new strain quite rapidly, where would we (either ARS or Methods) go to make the field collections? Probably not to Chiapas and perhaps not to the Yucatán peninsula. If we will have to go to Guatemala or Belize, or some other location, it is none too soon to start planning. If we go outside of Mexico we might need a field lab of some kind in which to establish lines, make crosses and rear the first few generations in that country. Or we might need the service of a light airplane that could make daily trips from a location such as Escuintla, Guatemala to Tuxtla.

"Where" is further complicated by the fact that neither ARS nor Methods has laboratory space well suited for use for strain development. In Methods they insist that they cannot rear more than one strain at a time. In ARS we routinely work with 20-30 strains at the same time but always with risk of contamination. If new strains will be developed at Tuxtla for the next several years obviously someone should provide a separate laboratory for use only for strain development.

In the meeting this week it was obvious that the Directors needed the option of being able to put VF-84 into the Methods strain change area and at the same time move O-83 to another rearing area where it could be maintained at reasonably high levels, say 5 million per week, reared by mass production techniques and thus be available for quick use if A-82 rapidly deteriorates and VF-84 should not be acceptable as a replacement. The only option available for O-83 was to move it to the ARS lab for rearing at a low level on a meat diet.

(3) When will the next new strain be needed and how many new strains will be needed in the next 5 years?

The A-82 strain has performed well for 16 months and perhaps would do so for another 16 months. Does this mean that no one needs to develop a new strain each year or on any other kind of calendar? When will the next new strain be needed by Production? If ARS had a definite date for when the next strain should be ready, we could do a better job of developing it. Another option that has been

R. A. Bram

suggested, that ARS constantly develop new strains, make them available when completed, and discard them if they are unwanted, is wasteful and completely unacceptable.

(4) Does the present strain development program impact adversely on the ARS program?

Yes, in several ways. To use our funds for routine strain development is a misuse of our appropriated funds. Our scientists who do the work correctly see it as damaging to their careers. It is not research but it takes No. 1 priority on their time, the limited space in the laboratory, vehicles, technicians, and funds. If we look ahead 5 years we cannot expect to keep a highly qualified research geneticist in our laboratory if that person is forced to give strain development No. 1 priority in the genetics program.

No matter how important strain development may be to the eradication program in the short run, there are genetic studies needed which are much more important to the program over the next 20 years. We sorely lack information about the basic genetics of the screwworm, information of the type that could be used to make major improvements in the technology of eradication. For example, with better genetic input, it is not unreasonable to expect that in the future a strain could be developed and managed in mass production so that it could be used 5 or 10 years, or even longer. Improvements in fitness for program use might make it possible to reduce release rates to one-tenth of the present rate. (Dr. Knipling has told us for years that in theory it should not be necessary to outnumber wild males with sterile males more than 3 to 1 but in routine program practice the ratio is more like 100 to 1 or perhaps 1000 to 1.

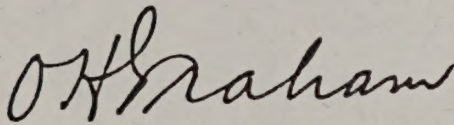
My point is that I do not feel that we should sacrifice our research program over a prolonged period of time to do a non-research job without at least pointing out to program officials what they are losing.

When sterile fly production was terminated rather abruptly in Mission in January 1981, and the laboratory colonies were exterminated, future strain development was one of the functions for which provision had not been made. The V-81 strain was at that exact time in a very critical stage - the final crosses were being made - and neither Fargo nor Tuxtla were prepared to receive the stocks. Since then we have heard a lot about what a bad strain V-81 was during the time it was in production, and even accusations that most of the programs problems in 1982 were caused by "the bad strain that ARS gave to the Commission". While I will always believe that V-81 deteriorated after it was placed in production (one should remember all of the labor and mechanical problems that prevailed in 1982, and especially the poor operation of the vacuum heads and failure to remove toxic wastes from the rearing vats), there can be no doubt that by August 1982 V-81 was a "bad" strain. We will never know for sure exactly when or why it went "bad", but if it was in fact a "bad" strain at the time it was placed in production, then it "went bad" between January and October 1981. And certainly neither ARS nor Methods at Tuxtla were at that time equipped or staffed to undertake strain development or strain change (previous strain changes had been accomplished by

R. A. Bram

changing first at Mission and then airlifting several million pupae of the new strain to Tuxtla).

I bring up past deficiencies not to accuse or defend, but solely in the hope that by recognizing them we will be able to avoid repeating past mistakes and improve the future handling of strain changes. If the eradication program progresses to the extent this year that we all fervently hope it will, next year is likely to be a year of major organizational changes. Its not too soon to try to decide what is most likely to happen and to prepare the best possible plan or plans for handling functions of major importance such as strain change. As long as the program is committed to changing strains at periodic intervals we all want all future strains to be of the highest possible quality.



O. H. GRAHAM
Location Leader

Enclosures

cc:

J. R. Johnston
N. L. Meyer
W. H. Sudlow
R. E. Reichard
C. J. Whitten
H. E. Brown
D. V. Petersen



THE UNIVERSITY OF TEXAS AT AUSTIN

AUSTIN, TEXAS 78712-7818

Department of Zoology

March 12, 1984

Dr. Robert Reichard
Dr. Nazario Pineda
Co-Directors,
Comision Mexico-Amricana Para Eradicacion del
Gusano Barrenador
Liebnitz No. 20-12^o Piso
Mexico 1, D.F.
MEXICO

Dear Drs. Reichard and Pineda:

I understand that there will be a Commission meeting in San Antonio on March 27. This is good news, since we have not been able to attend other meetings for a couple of years. I am looking forward to visiting with you and others in the Joint Program at that time.

I would like to have about 10 minutes scheduled to summarize our recent findings in Belize, and how they affect the maintenance of a screwworm free zone north of the barrier zone. I think this will be of general interest to producers, Commission members and scientists, alike.

Dr. John Ellison and I have in press (Annals of the Entomological Society of America) a detailed critique of the genetic studies of screwworms which shows how the differences reported by Dr. McInnis and others may be reconciled with ours. We hope this is a significant step in removing the controversy of these studies. He can present this material in summary form in about 20 minutes, and we will make copies of the detailed discussion available for those so inclined to study it later. Would you also please schedule his presentation sometime during the day.

Thank you for your courtesy. We are most anxious to hear the details of the program, which seems to be progressing better than ever before. This is, indeed, a happy state of affairs!

Sincerely,

R. H. Richardson
Professor

cc:
Dr. Ralph Bram
Dr. Norvan Meyer
✓ Dr. Hugh Graham



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

Dr. Graham

20 de Marzo de 1984.

A: Dr. Agustín Pagaza

*also see
file folder,
HEATED VATS*

Asunto: Charolas térmicas para la crianza

March 20, 1984

To: Dr. Ronald Lowe

Subject: Heated Rearing Vats

Por medio de este conducto comunicamos a ustedes que ha habido algunas discusiones los dos últimos meses acerca del uso de las charolas térmicas para la crianza en Tuxtla Gutiérrez. Estas discusiones han sido causadas aparentemente por el sindicato en Tuxtla Gutiérrez, pues ya que se pretende tener la temperatura reducida en el piso de crianza de la planta, para así hacer las condiciones de trabajo más confortables. La petición es muy razonable, pero hay muchos aspectos de esta petición que deben ser considerados. Durante los 19 años de operación de la planta en Mission, Texas se han usado charolas térmicas para la crianza. Originalmente cuando se construyó la planta en Tuxtla Gutiérrez se diseñaron las charolas térmicas para la crianza y uso de la planta y en principio se usaron durante las primeras operaciones. Después surgieron algunos problemas con las charolas térmicas en Tuxtla. Hubo algunos problemas con la humedad que entraba en las almoadillas térmicas causando cortos circuitos y los empleados podrían dañar o cortar las conexiones eléctricas. Por esto, era imposible para el depto. de Ingeniería y Mantenimiento reparar las charolas defectuosas tan seguido. Se llevo a cabo un proceso con respecto al uso de charolas no térmicas y para compensar se calentaba la temperatura ambiental. El resultado fue muy satisfactorio y el uso de charolas térmicas fue descontinuado.

El uso de charolas térmicas da una flexibilidad más grande durante el proceso de crianza de la larva además para permitir una temperatura ambiental más baja. La temperatura de las charolas puede ser más alta en los primeros grupos y más bajas en los últimos grupos. Esto puede

There has been some discussion the past two months about using heated rearing vats at Tuxtla Gutierrez. This is apparently an issue by the local union in Tuxtla Gutierrez in an effort to have the temperature reduced on the rearing floor of the plant in order to make working conditions more comfortable. The request is very reasonable but there are many aspects of this request which must be considered. During all 19 years of operation of the plant in Mission, Texas heated rearing vats were used. When the plant was constructed in Tuxtla Gutierrez heated rearing vats were designed for use in the plant and were in fact utilized during the early operation of the plant. Several problems soon evolved with heated vats at Tuxtla. There were problems with moisture entering the heating pads causing short circuits and employees would damage or cut the electrical connections. It was impossible for Engineering and Maintenance to repair the defective vats on a continuing basis. Trials were then conducted with the use of unheated vats and heating the ambient air temperature to compensate. The results were very satisfactory and the use of heated vats was discontinued.

The use of heated rearing vats provides greater flexibility during the larval rearing process in addition to permitting a lower ambient air temperature. The temperature of the vats can be higher during the early groups and lower during the later groups. This can assist with growth of larvae



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

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ayudar con el crecimiento de la larva en los primeros grupos y puede ayudar con la salida de la larva de la charola en los últimos grupos. Si se aumenta la temperatura de las charolas en los últimos grupos puede utilizarse para que la larva salga de las charolas. Esto puede ser probablemente las ventajas más grandes para usar las charolas térmicas.

Las desventajas incluyen un alto costo inicial y un alto costo de mantenimiento, con un diseño apropiado estos costos pueden probablemente reducirse y los problemas inherentes con el uso de las charolas térmicas pueden reducirse. Por lo que recomendamos que antes de que se fabrique una cantidad considerable de charolas térmicas y antes de que se invierta dinero se solicite al Depto. de Ingeniería y Mantenimiento que hagan un prototipo de diseños más avanzados para que sean probados por el Depto. de Desarrollo de Métodos o Producción. El prototipo puede incluir el uso de carrete eléctrico para calentar que sea sellado dentro de la charola con un cordón eléctrico y una conexión sellada dentro de un tubo. Otro prototipo podría utilizar vapor para calentar las charolas o agua caliente. Otro tipo puede usar aceite, sellado dentro de las charolas y calentado por carretes eléctricos también sellado dentro de las charolas. El personal del Depto. de Desarrollo de Métodos ha sugerido probar un sistema de alimentación continua con alimentos precalentados. Estas son sólo algunas ideas que se han presentado, e Ingeniería y Mantenimiento puede tener algunas ideas mejores. Sugerimos que tanto Ingeniería y mantenimiento como Desarrollo de Métodos y Producción trabajen juntos en el diseño como en las pruebas del prototipo. Cuando se acepte un prototipo que funcione entonces se deberá hacer un costo estimado para construir, modificar, o instalar estas charolas en el piso de crianza. Tanto el costo estimado como las proposiciones

during the early groups and can assist with the crawl-off larvae during the later groups. By increasing the vat temperature during the last group it can be used to drive larvae off of the vats. These are probably the greatest advantages for using heated vats.

The disadvantages include a high initial cost and a higher maintenance cost. With proper design these costs can probably be reduced and the problems associated with using heated vats at Tuxtla can be reduced. We recommend that before a large number of heated vats are made and before a large amount of money is spent on this that Engineering and Maintenance be asked to make some prototypes of improved designs which can be tested by Methods Development or Production. The prototype may include the use of an electrical heating coil that is sealed within the vat with the electrical cord and connection sealed inside a conduct. Another prototype may utilize steam to heat the vats or hot water. Another type may use heated oil sealed in the vats heated by electrical coils also sealed within the vats. Methods Development personnel have discussed trying a continuous feeding system using heated media. These are only some ideas which we have heard presented and Engineering and Maintenance may have some better ideas. We suggest that Engineering and Maintenance, Methods Development and production work together on design and testing of the prototypes. When an acceptable prototype is chosen then a cost estimate should be made to construct, modify, or install these vats on the rearing floor. The cost estimate and proposal should be submitted to the central office, for approval before proceeding due to the reduction in available funds that will probably occur in the coming months.



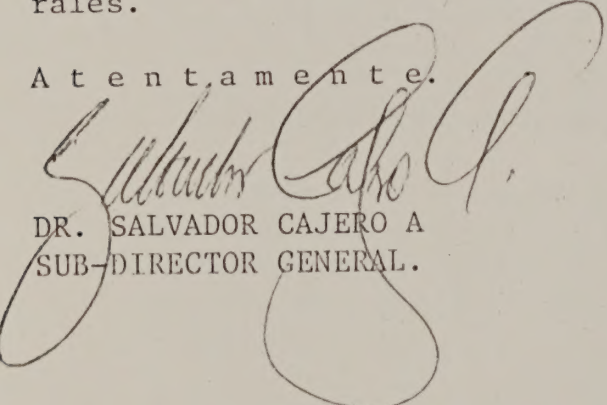
COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

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deberán ser enviadas a estas Oficinas Centrales para su aprobación antes de proceder a la ejecución de las mismas ya que posiblemente en los meses venideros habrá una reducción de fondos disponibles. Sentimos que no deberíamos cambiar el sistema de crianza precipitadamente ya que el sistema actual esta trabajando aceptablemente y el sistema anterior de charolas térmicas no funcionó bien. Una decisión precipitada podría ser costosa para el programa y pudiera ser que para ese entonces no pudieramos costearlo. Deseamos que este asunto sea cuidadosamente probado y justificado antes que procedamos a la operación. Por medio de este memo solicitamos sus comentarios respecto a este asunto tan importante. Sugerimos que todas las personas que tengan sugerencias se le envíen al Dr. Pagaza y al Dr. Lowe con copias para los Sub-Directores Generales.

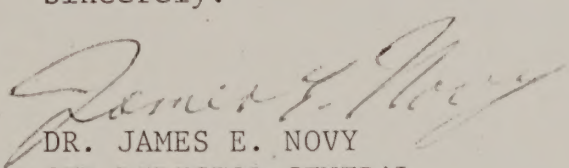
Atentamente.


DR. SALVADOR CAJERO A
SUB-DIRECTOR GENERAL.

c.c.p.: Dr. Nazario Pineda
Dr. Sergio Martínez
Ing. Eduardo Roveló
Dr. Luis Hernández
Sr. José María Domínguez

We do not feel that we should convert the rearing plant to heated vats hastily because the current system is working well and the previous system of heated vats did not work well. A hasty decision could be costly to the program at a time when we can not afford it. We urge that this matter be thoroughly tested and justified before we proceed to make it operational. By copy of this memo we solicit comments from others on this very important topic. We suggest that all comments be directed to Dr. Pagaza and Dr. Lowe with copies to the Sub-Director Generals.

Sincerely.


DR. JAMES E. NOVY
SUB-DIRECTOR GENERAL.

cc: Dr. Robert E. Reichard.
Dr. David Hoffman
Dr. H. C. Hofmann
Ing. Carlos Jiménez
Sr. Raúl Marroquín
Dr. Ed Gersabeck
Mr. William Sudlow
Dr. Hugh Graham
Dr. Harold Brown
Mr. Tom Lefler

JEN/lac.

RECEIVED MAR 26 1984

TRAVEL REPORT

Albany, CA

16 March 84

Hugh,

Tardy, but sent before (?) demanded --- demand lack indicates importance lack?

Seriously, I drafted the original in Tuxtla, but was never satisfied because I assumed such views were replotting what had been done by other in former years.

My thoughts could be summed by saying that temperature and pH are only obvious surface scratches. The important point is what "micro-environment" the screwworm is presented --- same thing you mentioned about the "old-timers" measuring the infected site on the animal.

The larvae stage is large and expensive, but the pupae deserve equal attention. Rearing should be controlled (is ??) on the micro-environment, such as the larval-cluster physical and chemical conditions, though that is now done (5/83) empirically through controlling room atmosphere and re-newing the liquid diet every four hours.

I am sending copies of the Travel Report to Charpentier, Mackley, Peterson, Harris, Dave Hoffman, Klassen, Bram, Smith, who were courteous and helpful.

If you are ever in California, please drop in. It would be a pleasure to see you.

Best wishes,

Bill

FOREIGN TRAVEL REPORT

Traveler: William Schultz, USDA Western Regional Research Center,
800 Buchanan Street, Albany, CA 94710, U.S.A.

Country: Mexico, 05 - 15 May 1983.

Purpose: Visit screwworm (Cochliomyia hominivorax) facilities at Mission, TX
and Tuxtla Gutierrez, MEXICO.

Summary:

As a visitor, I was looking for key process relationships in screwworm production to contrast with my prior housefly-medfly experience, plus screwworm acquaintance.

If viewing fly rearing as metabolic sequences within the Order Diptera, then both commonality and differences exist in mass-rearing ease and specialization. This is progressive through the housefly : medfly : screwworm : tsetse fly. Further, a field metabolic "key" is not necessarily a process "key" of the same priority when rearing under artificial conditions. A 50% mortality appears in the medfly and screwworm larvae which reduces yield from a production view, but which may be essential for perpetuating a good selection from an insect view. A 90% pupation and maturation yield appears to be good production efficiency, but this stage may be a more critical unit operation because the pupae are immobile and cannot migrate to a more desirable environment as can larvae. Medfly- and screwworm-pupae thermodynamics appear similar. This may also be fundamentally true for the larvae though the diets would appear to mask the similarities.

The visit raised interesting questions as to whether the field insect considers the ARS lab rearing, APHIS methods development, and APHIS production as metabolically equivalent, or whether the screwworm is merely adapting? And, whether the indoor rearing-environmental differences are significant to the screwworm product through successive generations? During the visit, pH and temperature measurements at the larval and pupal stages. Possibly, some of the differences will be worthy of an in-depth consideration. Perhaps too, directly controlling the process on the temperatures and pH's of larval-clusters and pupae could be considered further.

Such questions are best answered by the local ARS-APHIS-SARH personnel who are very capable and can monitor the insect product (consequences), rather than by a visitor who only sees fleeting, academic differences, then disappears-into-the-night.

Overall, the Tuxtla Gutierrez screwworm mass-rearing is a successful operation controlled by knowledgeable personnel, and the visit was both a pleasure and an informative privilege.

General:

This trip was an orientation on screwworm mass rearing as formerly practiced at Mission, Texas and as now performed at the joint SARH-APHIS facility near Tuxtla Gutierrez, Mexico. It included discussions with field, production, methods development, research, engineering, and quality-control personnel. Temperature and pH measurements were made on larvae and pupae for further information.

Preceding this visit, screwworm rearing had been discussed briefly with W. Klassen (then of ARS-NPS). He suggested considering *Phormia regina* as a screwworm model, similar to the housefly I previously used as a innocuous fruit-fly model in Albany.

As pre-trip preparation, I locally collected blowfly eggs (*Phaenicia*) on fresh beef liver and reared these through pupation. Differences in rearing behavior between the housefly and blowfly were noted, and used as a question base. This rearing also suggested minor instrumentation to take on the trip.

The first stop was a one-day visit to the APHIS facility at Mission, Texas on Friday, May 6th. Though now on standby status, it did provide both a contrast and historical view to the present Tuxtla operation. This included discussions with John Spencer, Robert Mangan of ARS and Tom Lefler, Joe Raimariz, and W. Sudlow of APHIS.

Arriving in Tuxtla Sunday morning May 8th, the day was spent with Hugh Graham (ARS-RL) and acquainting with the production-facility exterior. Each weekday I spent about four hours inside the screwworm facility, then had Saturday to sum my notes before leaving Tuxtla on Sunday and returning to San Francisco the same day, May 15th.

Hugh Graham arranged the visit at an excellent time when a variety of people were in town, both the regular full-time staff APHIS-ARS and other key people who are normally based in part or solely elsewhere, such as H. Charpentier, N. Meyer, C. Hoffman, F. Smith, R. Reichard, R. Harris, etc. In addition to Hugh Graham, a variety of local men were most helpful: J. Mackley, E. Gersabeck, D. Hoffman, R. Peterson, R. Brenner, R. Lowe, C. MacVean, S. DeCorso, I. McKey, and others.

My perspective and background differs from most personnel associated with the screwworm program because it was originally industrial bio-processing and only recently insect rearing. Therefore, this commentary is written as an amateur among professionals, but having mutual interests and experiences when the insect is viewed as a series of biochemical reactions. Such commentary is made with the reminder to the reader that Tuxtla is a most successful operation, and making changes for academic interest do not necessarily lead to significant improvements.

The measurements taken during the visit were likely no different than others have done. Some of that data is shown with commentary. These comments are not meant as direct suggestions, but rather are an out-sider's view that possibly might raise a meaningful question or two that will could be elaborated with the excellent talents and the in-depth experience of the local staff.

Larval-Diets and Room Temperatures.

1. Temperatures were measured with a 0.060-inch diameter SStl shielded type-K thermocouple probe coupled to a digital meter, indicating to the nearest 0.5°C. On a macro basis, and viewing Tuxtla as a large production facility, there were little temperature differences in particular areas, i.e. often less than 1°C.

On a micro basis, the differences were not so much in the liquid-diet vats or various parts of the room, but between the interior and exterior of a larval cluster. In contrast to housefly and medfly larvae which are grown in a solid diet, the temperature differences in the screwworm diet vats appear insignificant (external to clusters); hence, the need for management of heat generated within the liquid diet is negligible. Also, there seems a major contrast in the apparent lack of microflora growth within the screwworm diet as compared to houseflies and medflies under mass-rearing conditions. The major question may be to ask what is a significant temperature difference on a micro-basis -- hence to what precision should the temperature be controlled through room-heat management, i.e. -----

What should be the larval-cluster temperature?

And, is that cluster temperature requirement being met?

2. Around the perimeter and through the aisles, there are differences, such as between the center and perimeter. The nature of the liquid diet lends itself to a self-adjusting temperature control. As a future consideration if going to a gelled or other non-flow liquid, attention might be required to the reduced mobility of waste material, artifacts, and cluster heat. This heat (a quantitative factor) is mentioned as an entity to be "managed" so as to control the temperature (an intensive factor). Such a change could have a "cascade-effect" and require modification to the room air-conditioning load and distribution because the self-leveling evaporative (latent) cooling of the liquid diet would not be present. In such a situation, consideration could be given to equalizing the cluster temperatures in the top and bottom trays.

Note: These temperatures (see Table) were taken "once-a-day"; they are neither averages nor ranges which would reflect the true situation and the degree to which the factory rearing predisposes the screwworm quality.

Pupation and Pupae-Maturation Temperatures.

The pupation and maturation takes place in hardwood sawdust. The mass density of mass-reared screwworms is much greater than for wild insects. Hence, the opportunity exists for greater deviations in temperatures (7°C), particularly due to the heat of pupation (see Table)

Subsequent to this visit to the screwworm facility, I was able to do some brief investigation of medfly pupal heats. The temperature history of young pupae appeared to alter the responses of more mature pupae. Since pupae are immobile and cannot seek their preferred environment, as do adults and larvae, the pupa stage may offer future opportunities.

pH of the Larval Liquid Diet and Larval Clusters

Measurements were made to about 0.2 pH units using narrow-range pHyrion indicator paper to obtain a general pH profile throughout the diet pan. Differences in pH appeared to have potential biochemical significance, probably as others have previously investigated. As these pH differences are indicative of the reactions, they might be periodically reviewed as a simple check on the production well being. Undoubtedly the basic questions were answered years ago when the screwworm liquid diet was developed, but changes occur due to minor production-methods alterations.

ARS Lab Rearing ----- APHIS Methods Development ----- Factory Operation.

At the time of the visit, "apparent" differences in the three rearing methods were observed, but I was not able to distinguish between which were significant and non-significant differences in rearing environment, i.e. the human view of the in situ "averaged" macro-environment provided the screwworm versus the actual micro-environment the insect inhabits.

Likely, the observed differences are insignificant because when talking with ARS and APHIS personnel in December (ESA meeting in Detroit, Dec 1983), I understood that the 1983 screwworm strain was still propagating well and that field efficacy was excellent.

Liquid diet -- APHIS factory replaces the liquid 7-3-3 (% blood-milk-egg) diet every four hours while ARS rearing and selection uses larvae migration. These are potentially different micro-environments.

Egg Hatch -- APHIS factory at 39°C room air versus ARS 38-40°C water bath. The humidity differences, and effect with time on egg case integrity is a potential difference.

Pupal handling -- From heat rates and temperature profiles I made on medfly pupae from pupation through maturation, the subsequent pupae thermal-response (metabolic activity) appeared be readily disturbed. After thermal disturbance, it appeared that the pupae repeated part of the prior profile; these were "stray" observations in some preliminary work, but indicated that further work would be worthwhile. This impinges on the measured differences in pupal micro-environment (see Table).

Housefly -- nil housefly contamination in the ARS facility; significant housefly presence in the factory. No particular speculation on the significance.

Future -- If factory mass-rearing screwworms is viewed as a relatively new industrial technique (compared to silkworm), then we will see these skills progress from the present mix of empirical and theoretical techniques toward more detailed theory. Particular value seems to be offered by periodically reviewing practices with respect to the physico-chemical micro-environments rather than depending on averaged macro-environments. Therefore, from a thermal view, I consider the critical points to be the larval-cluster and pupal temperatures from larvae through imago. A fuller view should include the chemical constituents because minor changes in production methods can create major changes in the metabolism.

pH LARVAL-DIET LIQUID

(11 May 1983, prox 1530 hrs)

ROOM	GROUP	PAN Verti Posit'n	LARVAE AGE (days)	LOCALE (*Horiz locale in pan; **vert in liquid)						
				*	(Center)			(Edge)		
					** Btm	Mid	Top	Btm	Mid	Top
Main	5	3a	3.8		6.4	--	6.4	--	--	7.2w
Larv	5	3b	3.8		--	--	6.8	--	--	7.2w
	5	4c	3.8		--	--	--	--	--	7.1w
	5	4c	3.8		--	--	--	--	--	7.2w
	5	5c	3.8		--	--	6.2	--	--	--
	3	3	3.1		--	--	--	--	--	6.2
	3	4	3.1		--	--	--	--	--	6.4
	3	4	3.1		--	--	--	--	--	6.8w

Liquid Diet before feeding, pH 6.35 +/- 0.2

Random measurements, liq with nil larvae, 6.4, 6.4, 6.8, 6.2, 6.2, 6.4, avg = 6.4
 " " , larv-cluster surface liq, 7.2, 7.2, 7.1, 7.2, 6.8, avg = 7.1

Random re-measure of larvae-cluster surface liquid (13-V-83), range = 6.8 to 7.0

Factory water, 7.6 to 8.0, avg = 8.0

GROUP ROWS (double), A & B

GROUP 11-V-83 sequence 11-12-(01)-02-03-04-05-06-07-08-09-10

Pans (5) numbered Btm = 1, Top = 5.

PUPAE-BED TEMPERATURES [°C] (10 May 1983, prox 1230 hrs)

ROOM	AGE	PUPAE	BED DEPTH	LOCATION IN TRAY									
				HORIZ	CENTER			QUARTER			EDGE		
				DEPTH	Btm*	Mid	Top	Btm*	Mid	Top	Btm*	Mid	Top
Pupation	0.1	-0-	50		26.-	22.-	19.-	--	--	--	24.5	24.-	20.5
	0.9	100	25		21.5	21.-	19.-	--	--	--	24.-	22.-	21.5
Matur'tn	1.1	100	nm		--	--	--	16.-	17.-	16.-	--	--	--
	5.0	100	nm		--	--	--	17.-	18.-	19.-	--	--	--

Pupation & Maturation Beds = sawdust, hardwood

Nominal Room-Atmosphere Control

Residence Time, Pupation Room = 24-hours
Maturation Rm = 5.5-days

Pupation 28°C x 50% RH
Maturation 26°C x 70% RH

Remeasured on 13-V-83 in Pupation Room,
Age 0.2 days @ Ctr-Btm = 30°; Ctr-Top = 32°

* Inside of tray at bottom.



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research Lab
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

March 22, 1984

SUBJECT: Rearing of O-83 Strain by ARS

TO: Dr. J. D. Hoffman
Dr. Arturo Martinez y Tapia

To confirm our recent discussion of this subject, we in ARS will for an indefinite period of time rear a line of the O-83 strain in our laboratories. This line will come from the stocks which were recently passed to Dr. David Taylor by Methods Development for use in the comparison of adult emergence in the O-83 and A-82 strains. In addition to maintaining a line here in Tuxtla, we will send pupae to Fargo, ND so that Dr. C. J. Whitten can establish and maintain a culture of the same line of O-83 in his laboratory. The present plan is that Dr. R. D. Peterson will hand carry those pupae to Houston on March 31 and hand them to a courier from Fargo at Houston IAH.

O. H. GRAHAM
Location Leader

cc:

R. A. Bram
C. J. Whitten
D. B. Taylor
R. D. Peterson

SUMMARY

SCREWORMS IN BELIZE, C.A.

March 27, 1984

R. H. Richardson and J. R. Ellison
University of Texas at Austin

handout for
Commission meeting
in San Antonio

TYPES OF SCREWORMS

In the preliminary analysis of material collected in December 1983 and January 1984 from northern Belize we found 5 types of screwworms, three that were found in Chiapas, Mexico, one that is a new type, and one which we have not seen before but was karyotypically described in 1957. It was taken from the culture maintained at Kerrville, Texas.

The types of screwworms found did not seem to be randomly distributed. They seemed more or less clustered in the northern coastal area (within 5 miles of the coast), midrange area (20-50 miles from the coast) and inland area (over 60 miles from the coast). These patterns are tentative, and more identifications, as well as additional collections later this year are expected to clarify the picture.

Only the type that was reported in 1957 produced a wound with an odor characteristic of Texas screwworms found in past years. It was collected from a small head wound caused by an in-grown horn, and was easily smelled 30 or 40 feet away. The others, even if in wounds with hundreds of larvae, had no characteristic or offensive odor. All types, however, had the distinctive pigmented trachae of screwworm larvae, and adults grown from cultures where "typical" screwworm flies. More detailed morphological studies are underway by Dr. John Rawlins, who has visited The Smithsonian Museum and discussed the morphological features and questions with appropriate staff there. He is working with us in a "double blind" study so that when his work is finished we expect to have a clear understanding of the relationships between morphological diversity and karyotypic and biochemical diversity.

TREATMENT OF SCREWORM CASES

The most common medicine applied to infested wounds was known in Texas many years ago as Peerless Screwworm Medicine. It was replaced by Smear-62 and later treatments which had fly repellents. Ranchers in Belize do not usually need to treat wounds more than once, and do not need to pack Peerless-saturated cotton into larger wounds in order to get a one-time "cure." We were told that reinfestation of wounds is not a serious problem there. This does not imply that screwworms are not a problem to the producers, but that the nature of the problem differs somewhat from that we have experienced in Texas.

SIGNIFICANCE OF SCREWORM DIVERSITY TO ERADICATION EFFORT

Reintroduction of screwworms north of the barrier would be serious, indeed. If the type originally adapted to northern Mexico were reintroduced, it can be expected to expand more rapidly than those not typically found in the north. However, any kind of screwworms north of the barrier would present a very serious problem.

Recommendations

(1) Surveillance of the screwworm-free zone clearly is of paramount importance. The more people watching for an outbreak, the better. Since odor is not a reliable indicator, it is logical that veterinarians and ranchers be taught the morphological features of the larvae for field identification. Of course, continued submission of samples to a central location for confirmation of identification and recording is essential. An education program in Mexico and the U.S. emphasizing morphological identification would keep the public attention on a possible reintroduction, and should also improve the chances of sample submission from the earliest cases to occur in an outbreak area. We urge such an education program be initiated in the interest of improved surveillance, regardless of future eradication efforts.

(2) Reintroductions in the screwworm free areas may be expected to have limited genetic diversity. Furthermore, their genetic constitution may differ considerably from any being grown in a factory. Therefore, based on the effectiveness of low release rates seen in the Arriaga Test in 1981, a small number of sterile flies genetically matched to an outbreak should be very effective in its elimination. It would be easy to grow the necessary flies from collections taken directly from a reintroduction in a much smaller factory than that previously operated at Mission. Such a facility held "at ready" inside the U.S. seems justified, particularly if it could be used for other pest control programs or for research support when not needed for pest eradication. (Of course, this does not imply one would withhold sterile flies of any available kind from an outbreak until a matched type was brought into production.) We recommend the construction of such a facility within a hundred miles or so of the U.S.-Mexico border.

(3) We have not seen any collections suggesting asexual reproduction since the three collected near Tapachula, Chiapas, Mexico. However, we have requested assistance in obtaining more collections from this area. Any fertile egg masses in an area being treated with sterile flies are good candidates for having asexual reproduction potentials, since sterile flies likely would have little effect on such females. We recognize the logic and general desirability of extending the barrier zone to Panama, but there is the possibility of unleashing asexual types that are now held in check by sexual types. It is unlikely that asexual types would respond to sterile fly releases. There is, therefore, an urgent need to obtain more samples where these types were found. Furthermore, there is a corresponding need to monitor new zones of sterile fly release in order to detect such types should they appear later.



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR
LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

Ref./SOC/250/lvr

Marzo 27, 1984

A: M.V.Z. Sergio J. Martínez G.
Dr. Harold C. Hofmann
Entomologos Asesores

ASUNTO: PROPUESTA DE UNA PRUEBA PARA CONTROL DE CALIDAD

Adjunto el trabajo realizado por Richard D. Peterson II, Agustín Ocampo Candido y H. del Var Petersen, Intitulado "Longevity and Mating Capacity of Male Screwworms (Diptera:Calliphoridae)". En el cual se presentan observaciones muy interesantes entre la Longevidad y La cópula de machos criados artificialmente y machos silvestres a nivel de laboratorio. Es conocido que existen diferentes criterios sobre las desventajas del macho silvestre al someterlo a apareamientos en condiciones diferentes a las de la naturaleza. Sin embargo, considero que podría realizarse una prueba similar a la planteada en el trabajo mencionado, que de alguna forma pudiera ser utilizada para valorar a nuestras variedades de moscas en Tuxtla Gutiérrez, Chis. y con los datos que se obtengan periódicamente podrían ser interpretados para las decisiones de cambio de variedad o deterioro de las mismas.

En espera de saber sus consideraciones, quedo de ustedes.

Atentamente.

M.V.Z. Moisés Vargas Terán
Subdirector Operaciones de Campo

M.V.Z. Nazario Pineda Vargas/D.V.M. Robert Reichard.-Directores
c.c.p. M.V.Z. Salvador Cajero/D.V.M. James E. Novy.-Subdirectores Gales.

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c.c.p. M.V.Z. Agustín Pagaza Garza/DR. Ronald E. Lowe.-Directores Planta de
Producción Tuxtla Gtz. Chis.
M.V.Z. Arturo Martínez y Tapia/Dr. David Hofmann.-Tuxtla Gtz. Chis.
Dr. H. Graham.-Tuxtla Gtz. Chis.

MVT/lvr

Longevity and Mating Capacity of Male Screwworms (Diptera: Calliphoridae)¹

RICHARD D. PETERSON II,² AGUSTIN OCAMPO-CANDIDO,² AND H. DEL VAR PETERSEN¹

J. Econ. Entomol. 76: 1262-1264 (1983)

ABSTRACT In the laboratory, the mating capacity of individual mass reared, irradiated and nonirradiated wild-type male *Cochliomyia hominivorax* (Coquerel) was evaluated. Each day males were offered 1 or 5 6-day-old sterile or wild-type virgin females during their life. Wild-type males lived twice as long (25 days), remained sexually active three times longer (17 days), and mated twice as many times during their life compared with sterile males. During the first 8 days of mating life, sterile males in both crosses had a percentage of mating similar to that of wild-type males mating with wild-type females. Wild-type males mated fewer times when crossed with sterile females. Sterile-male mating activity was highest when males were 4 to 8 days old. Mating between wild-type males and females peaked at 8 days of age. Males generally chose mates in more advanced stages of ovarian development.

The success of an insect control program based on the sterile-male technique is dependent upon the degree to which sterilized males are successful in mating with native females. An important factor, expressed as male mating frequency and longevity, is the mating capacity of the sterile males produced for release. Several aspects of mating capacity of male screwworm, *Cochliomyia hominivorax* (Coquerel), have in the past been studied to provide information for the USDA Screwworm Eradication Program.

Bushland and Hopkins (1951) reported that wound-reared males mated up to 11 times if virgin females were readily available. In a study of male sexual vigor, Baumhover (1965) found that, when males were caged with females for 3 days at a ratio of 2:80, each successfully inseminated an average of 17 to 18 females. Alley and Hightower (1966) reported that males of a recently colonized strain mated with a mean 1.5 females of the same strain in 1 h, whereas males of an older strain mated 2.9 to 4.9 times with females of a newer strain. Crystal (1967) found that male mating activity remained high during 3 to 7 days postemergence and female receptivity gradually increased during days 3 to 14. When Hightower et al. (1972) caged single, irradiated males with 10 irradiated females from 1 to 6 days postemergence, they found each male mated 4.6 to 9.4 times, and the frequency was correlated with their previous larval weight. Adams (1979) reported maximum male mating vigor for 4 to 16 days postemergence, whereas female mating frequency was low until day 5 of adult life.

Recently, there has been renewed interest in producing an all-male strain for use in the screwworm eradication program (LaChance 1979). Eradication efforts which release sterile females have also been questioned. Our study was conducted to determine the mating capacity of mass-reared, sterile males, like those destined

for field release, and wild-type (F₁) males during their entire life span in the laboratory.

Materials and Methods

Data were collected on the longevity and mating capacity of 120 individual male screwworms. The sterile adults were from the Sinaloa strain and had been in production ca. 6 months in the USDA-SARH screwworm mass rearing facility near Tuxtla Gutierrez, Chiapas, Mexico. As larvae they had been reared on a hydroponic medium (Gingrich et al. 1971) and routinely irradiated as 5.5-day-old pupae. Wild-type fertile adults were F₁ progeny of individual egg masses collected from sheep on the Pacific coast of Chiapas. Wild-type larvae were reared in the laboratory on a ground-meat and dried-blood medium (Melvin and Bushland 1940), and the adults were not irradiated. The crosses studied were wild-type males + wild-type females, wild-type males + sterile females, sterile males + wild-type females, and sterile males + sterile females at a male-female ratio of 1:1 or 1:5. Each mating combination was replicated in 10 cages. The 1:1 series consisted of 10 males; for the 1:5 series, 20 individual males were used for each cross, respectively.

Adults used in the study were sexed without anesthesia < 24 h after eclosion (Rogoff et al. 1980, Crystal 1967). Males were individually caged from 1 day postemergence until their death and were daily provided with either 6-day-old, sterile virgin females or wild-type F₁ virgin females from a single egg mass. Females of each type were caged together until offered to a male. Wild-type males from the same egg mass were used in both wild-type and sterile female crosses. After being held with males 24 h, females were removed from the cage, and their spermathecae were squashed and examined for the presence of sperm. The ovaries of wild-type females were also removed to determine the stage of egg development. Oogenesis is divided into a series of 10 stages, where the germarium is defined as stage 1, and the mature egg as stage 10 (Adams and Reinecke 1979). The irradiation treatment prevents ovarian development in sterilized females (LaChance and Bruns 1963).

All adults were held in gauze-covered cages (12.5 by 12.5 by 30.5 cm) and provided with honey and water.

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Table 1. Median of male screwworm mating activity when offered 1 or 5 6-day-old virgin females each day of the male's life^a

Male type	Days to first mating	Mating life span (days)	Day from last mating to death	Life span
Wild	5.0 (3.5-5.5)	17.0 (12-27)	2.0 (1-5)	25.5 (19.5-3.3)
Sterile	4.0 (3-5)	6.0 (4-7.5)	3.5 (1-5)	12.0 (9-16.5)

^aEach value represents the median for 60 males; values within parentheses represent the interquartile range, i.e., center 50% of the observations.

Mean maximum and minimum temperature and relative humidity (RH) during the test were 27.4 and 24.4°C and 74.1 and 54.6%, respectively. Photoperiod was maintained at LD 8:16, but natural light through laboratory windows was also present. Data were analyzed by non-parametric statistical techniques.

Results and Discussion

A summary of selected parameters measured during male mating (1:1 and 1:5) activity is presented in Table 1. Wild-type males lived 2.1 times longer and had a mating life span 2.8 times that of sterile males. Although mating frequency (1:1) was similar during the sterile and wild-type males' lifetime, wild types mated 1.6 more times during their mating life. In the 1:5 crosses, mean longevity was 2.2 and 4.6 days less for sterile and wild-type males, respectively. Mating life span also declined, whereas wild-type males mated 1.4 and sterile males 1.6 times more in the 1:5 crosses. Both sterile and wild-type males mated more frequently each day of their lives, probably reflecting the greater number of mates available and a range of female receptivity.

In comparing sterile and wild-type male 1:1 crosses with wild-type females, both sterile and wild-type males mated with females having a mean egg stage development of 5.1. However, there was a wide range in the egg stage of females that mated. One sterile male at 3 and 4 days of age mated with wild-type females that were in egg stage 3. On day 5, the same male did not mate with a female in stage 10 but mated at 6 days with a female in egg stage 5. Another sterile male first mated when 4 days old with a female in egg stage 4. He then mated for the next 4 days with females in stages 6, 6, 10, and 10, respectively. Wild-type male mating behav-

ior with females in advanced egg stages was similarly variable. Since only 57% of the wild-type females in egg stages 8 to 10 were mated after their 24-h exposure, male age, mating history, and a lack of a choice of females probably influenced whether mating occurred. Adams (1979) reported that mating occurred when females had eggs at developmental stages 4 to 10, but the greatest proportion of females had been mated by egg stages 7 to 10.

The mean egg stage of wild-type females mating in the 1:5 crosses was 6.8 when mating with sterile males and 7.2 when mating with wild types. Eggs were about two stages more developed than those of mating females in the 1:1 cross; this may reflect male preference when given a choice of females with advanced egg stages. Overall, 76% of the females inseminated each day had a mean stage of ovarian development as long as or longer than that of females that did not mate.

Mating performance of sterile males in both crosses of the 1:5 tests was similar with respect to mean longevity, total matings, and percentage of males mating at various ages. Sterile-male mating activity increased steadily and was high at 4 to 8 days of age (Table 2). Wild-type male mating activity with wild-type mates was high from 5 to 10 days of age. Thereafter, there was a general reduction in the numbers of matings through day 14. Kaufman and Wasserman (1957) reported similar results when unirradiated males were individually caged with 25 females for 1-week periods. The greatest mean number (6.2) of matings per male occurred during the first week and declined to 3.0 during the third week. Cytological studies have shown meiotic activity in the testes throughout the life span of the normal male screwworm, although the activity was much reduced in old males.

Sterile males had sufficient sperm to inseminate up to 11 (1:1) or 21 (1:5) caged females. Earlier studies have indicated that the irradiation treatment at 6,000 rads to male pupae destroyed spermatogonial cells and thereby permanently halted the early stages of spermatogenesis (Kaufman and Wasserman 1957, Riemann 1967). This is probably the reason our sterile males had shorter mating spans.

Mating activity in the wild-type $\times$ sterile cross was half that of wild $\times$ wild crosses and was less easy to characterize. Instead, 8 to 18% of the females were inseminated each day during male age 5 to 10 days. During the same period, wild $\times$ wild crosses had 10 to 16% more matings daily. Fifty percent mortality of sterile

Table 2. Percentage of female screwworms mated during days 2 to 14 of male life

Male:female (1:5)	Male age in days ^a												
	2	3	4	5	6	7	8	9	10	11	12	13	14
Wild $\times$ wild	0	2	7	18	22	27	34	26	26	16	14	17	12
Wild $\times$ sterile	1	7	10	8	12	12	18	15	13	18	17	18	13
Sterile $\times$ sterile	1	9	27	25	27	26	27	9	7	7	3	4	0
Sterile $\times$ wild	5	15	27	29	25	32	16	18	3	0	2	0	2

^aPercent based on total females offered surviving males.

Table 3. Percentage of male screwworms mating during mating life span

Male × female (1:5)	Male age in days ^a			Total matings
	2-5	6-8	9-14	
Wild × wild	25b ^b	26a	15a	340
Wild × sterile	18c	11c	12a	216
Sterile × sterile	30a	17b	4b	156
Sterile × wild	30a	17b	1b	159

^aMale age is adjusted, based on when males began to mate.^bPercentages within columns followed by the same letter are not significantly different at $P < 0.05$, based on binomial distribution.

males occurred at ages 11 and 13 days in sterile and wild-type female crosses, respectively. Although sterile males were not given a choice regarding mates (sterile vs. wild-type females), they appeared equally attracted to sterile females given their availability.

Table 3 presents male mating performance during the mating life span. During days 2 to 5 of mating life, sterile males mated 5 to 12% more than wild-type males. At 6 to 8 days, wild × wild mating activity remained high, whereas sterile-male crosses declined 13%. At 9 to 14 days into the males' mating life, sterile-male crosses were significantly higher.

There was 1.6 times more mating during their lifetime between wild-type mates (340) than with wild-type × steriles (216). No wild-type male mated with sterile females more than three times in a day. Three wild-type males, however, mated on three occasions with all five wild-type females. Mean egg development of these mated females was 10.0, 9.8, and 7.4 and male ages were 7, 16, and 20 days. Two of the males had mated four times with females 10 days before, and then four and six times more before mating with all 5. However, on 35 other occasions when mating occurred and the mean stage of egg development was 8 to 10 for all females, only once did a male mate even four times.

A sterile 1:1 male in both the sterile and wild-type female cross mated on 7 consecutive days. Similarly, a wild-type male mated for 7 consecutive days with sterile females; however, the wild-type × wild-type cross produced a male that mated on 9 consecutive days.

Overall, in the 1:1 and 1:5 crosses wild-type males outperformed sterile males during their lifetime. Wild types lived twice as long, remained sexually active three times longer, and mated about twice as often as that of their sterile counterparts. However, during days 2 to 5 of the sterile males' mating life, they were more sexually active than wild-type males. Since males were not given a choice of sterile or wild-type mates, it is difficult to assess the role of sterile females in the field. Sterile males mate as readily with sterile mates as with wild types. Given the greater mean densities of sterile flies

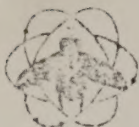
in a release area, most sterile males may only encounter sterile females. With peak sterile-male mating activity at 4 to 8 days of age, twice-weekly aerial releases could prevent periods when sterile males already on the ground might be less sexually active.

Acknowledgment

We express our appreciation to J. W. Mackley, C. J. Whitten, and D. O. McInnis, ARS, USDA, participants in the screwworm eradication effort. Also, we thank T. Gallegos, Technician, Screwworm Research Laboratory, Tuxtla Gutierrez, Chiapas, Mexico.

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COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

COMTA 24363

KM. 2 CARRETERA A LA ANGIOSTURA
CHIAPA DE CORZO, CHIS.

ANEXO POSTAL 544

Abril 4, 1984

Ref: PGD*158

Para: DR. H.O. GRAHAM
Jefe del Depto. de ARS.

Asunto: Recepción de la cepa Villa Flores 84 en
Cambio de Cepa.

Por este conducto informamos a usted que hasta esta fecha hemos recibido 4 lotes de pupa de la nueva cepa VF-84, los datos son los siguientes:

FECHAS:

Pupación:	Recepción:	Volumen:	Irradiado:
26/III/84	30/III/84	3.5 l	31/III/84-350 ml
28/III/84	30/III/84	3.9 l	03/IV/84 -350 ml
31/III/84	01/IV/84	2.27 l	
01/IV/84	02/IV/84	1.7 l	

Las observaciones generales que tenemos al respecto del 1° y 2° lote son:

1a. Mucha pupa anormal. (Seca y podrida aproximadamente entre el 40 y 50%).

2a. Heterogénea la edad de la pupa.

3a. Emergencia tardía.

4a. El peso promedio del 1er. lote fue de 49.8 mg y del segundo lote 48.26 mg.

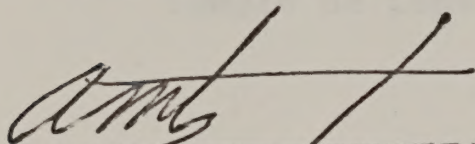
Pág. No. 2

Estamos realizando todas las pruebas rutinarias de Control de Calidad con material biológico estéril a fin de obtener la mayor información posible desde los inicios de esta nueva cepa.

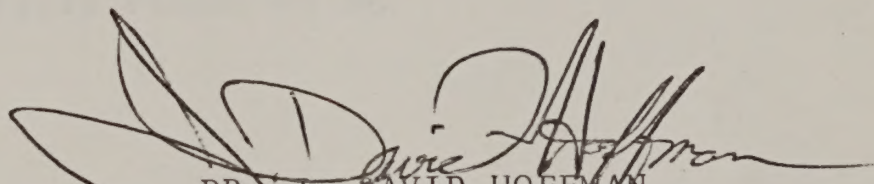
De antemano sabemos que es temprano para tener un juicio al respecto, sin embargo deseamos poner a su consideración estas observaciones y le agradeceríamos sus comentarios.

Sin más por el momento, nos es grato saludarlo.

Cordialmente.



DR. ARTURO MARTÍNEZ Y TAPIA
Jefe del Depto. de Investigación
y Desarrollo Experimental.
Sección Mexicana.



DR. J. DAVID HOFFMAN
Jefe del Depto. de Inv. y
Desarrollo Experimental.
Sección Americana.

c.c.p. Dr. Agustín Pagaza Garza/Dr. Ronald E. Lowe
c.c.p. Entomólogos Asesores.- Oficinas Centrales.
c.c.p. Dr. David Taylor. ARS.
c.c.p. Archivo/Consecutivo.



COMISION MEXICO-AMERICANA PARA LA ERRADICACION DEL GUSANO BARRENADOR

LA ENERGIA ATOMICA AL SERVICIO DEL GANADERO

COMTA. 24363

KM. 2 CARRETERA A LA ANGUISTURA
CHIAPA DE CORZO, CHIS.

APDO. POSTAL 544

Abril 4, 1984

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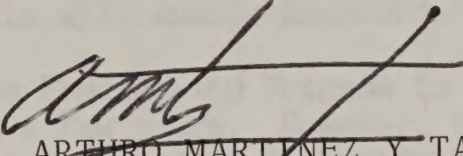
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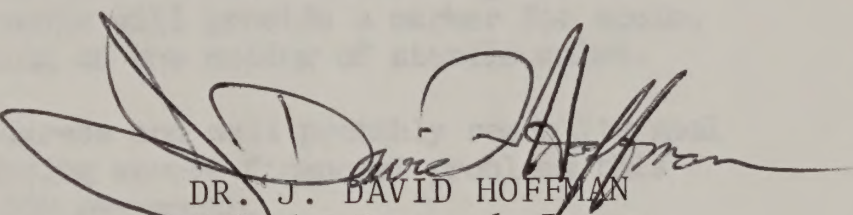
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Sin más por el momento, nos es grato saludarlo.

Cordialmente.



DR. ARTURO MARTÍNEZ Y TAPIA
Jefe del Depto. de Investigación
y Desarrollo Experimental.
Sección Mexicana.



DR. J. DAVID HOFFMAN
Jefe del Depto. de Inv. y
Desarrollo Experimental.
Sección Americana.

c.c.p. Dr. Agustín Pagaza Garza/Dr. Ronald E. Lowe
c.c.p. Entomólogos Asesores.- Oficinas Centrales.
c.c.p. Dr. David Taylor. ARS.
c.c.p. Archivo/Consecutivo.



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Office of the
Regional Administrator

RECEIVED APR 15 1984
701 Loyola Avenue
P.O. Box 53326-56189
New Orleans, Louisiana
~~70153~~ 70156-6189
JTF
PDP

April 6, 1984

SUBJECT: Mexico-American Screwworm Commission Meeting,
San Antonio, TX, March 27, 1984

TO: T. B. Kinney, Jr.
Administrator

I attended the subject meeting as your representative and introduced Dr. Hugh Graham, who presented some research results indicating that a fluorescent dye added to the growth media will provide a marker for sperm. This will enable improved field testing of the mating of sterile males.

The Eradication Program is making progress and will probably reach its goal in a few years. However, they are having severe financial problems this year: a projected shortfall of \$200,000 per month.

The evening before the commission meeting there was considerable discussion of extending the Eradication Program through Central America to Panama at a meeting of the South West Animal Health Research Foundation. This possibility received some additional discussion at the commission meeting. It appears that over the next couple of years there will be support developed for this proposal among the livestock growers in the United States, Mexico, and the other Central American countries.

ARS may be asked to conduct some research in Guatemala or another country for testing a new strain of the fly.

I am providing Ralph Bram with a copy of my more detailed notes and a copy of the handout material.

M. H. Frere

M. H. FRERE
Acting Associate Deputy Administrator

cc:

Ralph Bram
✓ Hugh Graham

P.S. Thanks so much for sharing board and room with me. I look forward to reciprocating when you visit N.O.

*see copy w/enclosures
in 39th Commission meeting
folder.*



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains Area

046
P.O. Box JJ
College Station, Texas
77841 - 5125

April 16, 1984

SUBJECT: Reports and Plans - Tuxtla, Mexico

TO: P. A. Koenig
Southern Region, ARS
New Orleans, LA 70156-6189

We are enclosing three copies of the subject report and plan. Also enclosed are two sets of AD-421 as requested. One set of the Report and Plan has been sent to D. Niffenegger.

Ellen

ELLA L. FLYNT
Secretary

Enclosure

CC: O H Graham

a copy of the report and plan
filed in folder
1983-84 Report and
Plan



United States
Department of
Agriculture

Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research Lab
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

April 16, 1984

Mr. William G. Schultz
Food Technology Research
USDA-ARS-Western Regional Research Center
800 Buchanan Street
Berkeley, Calif. 94710

Dear Bill:

No, I did not "demand" your trip report but was very pleased to receive it. Thank you for a very informative account of your visit to the mass production facility in Tuxtla.

The 15 months period, 1983 and 1984 to date, has been a period of outstanding program progress. Only 8 naturally occurring screwworm infestations (verified cases) have been found north of the critical line (port of Veracruz to Acapulco) since January 1 and sterile flies are being distributed throughout the future barrier zone. It seems probable that the goal of eradication to the Isthmus of Tehuantepec will be achieved by the end of 1984.

In view of this program success and anticipated budget reductions interest in improved rearing technology has diminished. This attitude could change quickly for any of several reasons and there will be intense interest in building in the best possible technology into any new rearing plant which might be designed for use in Central America.

You will be interested in reading the enclosed copy of a memo by Drs. Novy and Cajero on the subject of heated rearing vats. I anticipate additional discussion of this subject but doubt that we will see the present vats replaced with all new vats. I do agree with Dr. Novy that the subject is sufficiently important to justify the design and testing of a new prototype heated vat. Best regards.

Sincerely,

O. H. GRAHAM
Location Leader

Encl.

cc:

R. A. Bram (w/enclosures)
H. E. Brown (w/enclosures)
R. L. Harris (w/enclosures)

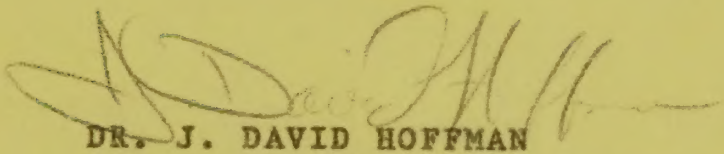
April 17, 1984

Subject: Effect of temperatures on Egg Incubation
and larval development.

To: DR. WILLIAM RUBINK,
Research Entomologist
ARS, Tuxtla Gutierrez, MEXICO

* I would appreciate publication(s), reports, personnel observations on the subject topic.

* Sincerely,



DR. J. DAVID HOFFMAN
Chief of Methods Development.

cc. Dr. Agustin Pagaza/Dr. Ronald E. Lowe.
cc. Dr. Hugh Graham
cc. Dr. Arturo Martinez y Tapia
cc. Biol. Rene Garcia/Mr. Charles MacVean
cc. IBQ. Felipe DeLa Cruz.
cc. Biol. Raquel Courtois.
cc. Files.

April 17, 1984

Subject: Effect of temperatures on Egg Incubation
and larval development.

To: DR. WILLIAM RUBIN,
Research Entomologist
ARS, Tuxtla Gutierrez, MEXICO

* I would appreciate publication(s), reports, personnel observa-
tions on the subject topic.

* Sincerely,

DR. J. DAVID HOFFMAN
Chief of Methods Development.

cc. Dr. Agustín Pazas/Dr. Ronald E. Jones.
cc. Dr. Hugh Graham
cc. Dr. Arturo Martínez y Tapia
cc. Biol. René García/Mr. Charles MacVean
cc. IBQ. Felipe Deela Cruz.
cc. Biol. Rafael Contreras.
cc. Files.

04/18/84

Bernie -

Thanks for sending me a copy of your reasonable reply to Ray Sagné. Like Ray, I feel that the UT workers have for more than 6 years presented only unproved hypotheses, not evidence, of reproductively isolated or partially isolated screwworm populations in Mexico and I deplore any credence which ~~accrue~~ might accrue to their views simply because they strongly and skillfully assert those views. Otherwise, I found your paper interesting and certainly worthy of publication. We can all agree that we need to know a great deal more about the population dynamics, habits, behavior and ecology of the screwworm in both Central and South America -

Best personal regards,
Hugh





THE
UNIVERSITY
OF
ILLINOIS
AT
CHICAGO

Department of Biological Sciences
College of Liberal Arts and Sciences
Box 4348, Chicago, Illinois 60680
(312) 996-2211

March 28, 1984

Dr. Ray Gagné
Systematic Entomology Lab, USDA
c/o U.S. National Museum NHB168
Washington, D.C. 20560

Dear Ray:

Thank you for taking time to send me your comments in your recent letter. I always appreciate your suggestions concerning our blow fly work in Peru. I was surprised, however, at the vehemence of your response. I want to emphasize that neither you nor your ideas were being attacked. We collected and studied over 25,000 Peruvian blow flies so you and I both know that there's not much ammunition in 13 specimens to justify our getting into the hominivorax controversy. But it feels like we've stepped on a landmine.

Your response misreads our intent. Before introducing our morphological comparisons we say on page 218: "Despite intensive study of Mexican and other populations, there is no consensus on the meaning of the variants which have been described by the Richardson group (LaChance et al 1982 and reply by Richardson et al 1982b). Whatever their ultimate status, these genitalia differences are reported here with the clear understanding that they are based on a very small sample and are meant to serve primarily as a stimulus and guide for future research on South American hominivorax."

Why attribute more than we intended? At most, this was a very limited study based on a small number of specimens we were able to collect in two trips, and on a few museum specimens. In this context, we felt justified in presenting the material as a preliminary paper, certainly not as a definitive one. Moreso, because the flies are in Peru, yet possibly the only reference to them is that of Arribalzaga in 1880.

At the end of the paper we repeat this caveat: "Our observations are preliminary to a much needed thorough study of the distribution, biology, and variability of hominivorax populations in South America as a basis for their eventual control."

re the "window." On page 218, after pointing out differences and similarities in the genitalia, including the window, in four flies reared from the same wound, we conclude: "These differences suggest that variation can occur within a single brood." Other differences are reported but again we thought it would be useful to do so, not with any covert intention of exposing cryptic species. Now it is quite possible that these differences are of little or no value, or some may be worth following up. You are better able to pass judgement since you have studied hundreds, perhaps thousands, of specimens and neither I nor Baumgartner have.

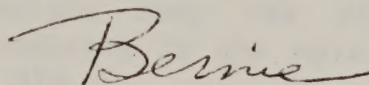
The differences in the apodemes shown in Fig. 2 are not only of length but of shape. The flies were killed less than 12 hours after eclosion, as stated. I have no other data on the flies, except that the larvae were mature maggots when taken with blood from the wound and pupariated 24-36 hours later in sawdust. The temperature in Pto Bermudez was a few degrees (C) higher than in San Ramòn. I have no interpretation of the somewhat dissimilar apodemes.

Baumgartner's original manuscript was much overblown and I take responsibility for letting it get past me. It is not my usual style. This one is toned-down and unambitious.

I trust the Chrysomya paper went down better.

Baumgartner may wish to make his own response--after all, he's the senior author.

Sincerely,



Bernard Greenberg
Professor

BG/ss

cc: R. Bram
N. Woodley
O.H. Graham
L.E. LaChance
J. Wendell Snow



United States
Department of
Agriculture

Agricultural
Research
Service

Northeastern Region

RECEIVED APR 3 1984

Systematic Entomology Laboratory, USDA
c/o U.S. National Museum NHB 168
Washington, D.C. 20560

March 22, 1984

Dr. Bernard Greenberg
Department of Biological Sciences
University of Illinois at Chicago Circle
Box 4348
Chicago, IL 60680

Dear Bernie:

Thank you for the copies of the Chrysomya and Cochliomyia papers by Baumgartner and Greenberg. I was amazed to see Fig. 2B and read the discussion about morphology in "The primary screwworm fly..." [ESA common name?], Revista Brasileira de Biologia 43:215-221, 1983. As I pointed out in my letter to you of October 19, 1982, an aedeagus overcooked in preparation with KOH or NaOH will often develop a break in the membranous outer casing to allow the stiff, longitudinal rods to pop out. I also cautioned that the "window" varied in size from one side to another. To report those items without a caveat as you have done is harmful and misleading.

Any paper purporting to discuss fine anatomical variation should take more than 13 specimens from 5 localities into account, particularly when many more are readily available. I hope readers of the paper have a critical sense. They may wonder why any effort was made to relate these specimens to the alleged 9 "types" of screwworms from northern Mexico.

I never expect an author to accept every criticism in a review. It's his paper. But if an author disagrees with a point, especially one in apparent error, he has to at least explain away the difficulty. To publish a misleading figure such as 2B is contrary to the spirit of the statement at the end of your first paragraph on p. 218.

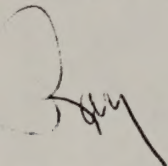
Apodemes are notoriously variable in insects. I remember J. R. Ellison speaking in Texas about the "growth rings" of these and the hypandria. He thought that those two structures grew longer with age. You state, though, that your specimens were killed before 12 h old. If that is correct, the specimens would have to add growth rings at a fast rate, if indeed they did. I think I remember Ellison speaking about that taking a matter of days. I just spoke about this with a visitor, G.C.D. Griffiths, from Edmonton, Alta. He says their length is a function of age in anthomyiid flies, also. Depending on the species, it's a matter of hours to days before the apodeme is long enough so that mating can be effected. That the apodeme must lengthen

Dr. Bernard Greenberg

2

enough to mate may be why screwworm males don't mate for the first day. If both of your examples were killed before 12 h old, perhaps one was killed much sooner after emerging than the other.

Sincerely,



RAYMOND J. GAGNÉ
Research Entomologist

cc:

R. Bram
N. Woodley
O. H. Graham
L. E. LaChance
J. Wendell Snow

QUARTERLY REPORT ON SELECTED ARS RESEARCH PROJECTS
Agricultural Research Service
U.S. Department of Agriculture

INSECT AND WEED CONTROL RESEARCH

A SPRAY-ON BIRTH CONTROL FOR COCKROACHES called hydropene is the latest chemical weapon to battle this pest. Manufactured by a commercial firm, hydropene was found in tests to prevent the birth of cockroach offspring. ARS reports that a single spraying throughout a 100-unit apartment complex in Gainesville, Florida, had cut the roach population 95 percent eight months later.

A COOPERATIVE RESEARCH AGREEMENT was signed with Brazil in April to find new biological weapons to control the imported red fire ant, which now infests 230 million acres in nine Southern states.

ONE PROMISING CONTROL FOR FIRE ANTS is a synthetic hormone that mimics the pest's juvenile hormone. Researchers baited ant colonies with soybean oil and corn grit laced with tiny amounts of hormone. Worker ants carried the lethal bait into the colonies, where the food was regurgitated and fed to the queen and to immature ants. Under the hormone's influence, immature ants developed into drones instead of workers. Without workers to gather food and tend the broods, the fire ant colonies soon crumbled and eventually disappeared. A chemical company is now manufacturing the hormone.

INSECT NEUROCHEMISTRY is a science that studies the insect's brain and nervous system to learn what causes behavior. If the chemistry in the brain that dictates behavior can be disrupted, the resulting false signals can halt molting, upset mating, realign hormones or prompt other fatal reactions. Current research is trying to interrupt the production of sex attractants in the corn earworm moth...Isolate hormones in the housefly to learn what effect they have on specific cells in the fly's body...Isolate hormones in the stable fly that control the insect's muscle contractions. As research unlocks the intricacies of the insect brain, this scientific work will lead to a new class of safer insecticides which alter the behavior of insect pests without harming other living things.

A VIRUS LETHAL TO A WHOLE CLAN OF INSECT PESTS, including cotton budworms and bollworms, can be sprayed on cotton plants and will kill caterpillars soon after they attack the boll. After death, a caterpillar corpse disintegrates when touched, releasing billions more virus particles that are deadly to live caterpillars nearby. The developer of the virus reports that "the potential for biological control agents has scarcely been tapped."

A FIRST-OF-ITS-KIND PROCESS for encapsulating biological or chemical herbicides in water-absorbent gels made from algae has been developed by ARS scientists. The gels contain the herbicides for controlled release. Although still too expensive for commercial use, the process will be useful to researchers attempting to solve weed-control problems.

A CHEMICAL SCENT MAY SOON ATTRACT armies of "friendly" spined soldier bugs to a single field, where they can feed on a wide variety of crop-destroying insects.

The soldier bugs feed on insect larvae, so pests are killed at the stage when they inflict the most damage to crops. After the pests are destroyed, the scent, called a pheromone, could be used to lure the soldier bugs to another field to feed on more insects, while any pests remaining in the first field are mopped up with pesticides.

TESTS SHOW THAT COCKROACHES and mosquitoes are in fact not repelled by ultrasonic gadgets commonly sold through the mail, nor do they keep the mosquitoes from biting. The U.S. Postal Service asked ARS scientists to check the effectiveness of these products.

NEW GUIDELINES FOR MATCHING application rates of commonly used herbicides to soil properties will help farmers adjust amounts of chemicals to soil changes resulting from changes in tillage practices.

CROP RESEARCH

APPLYING INFINITESIMAL AMOUNTS of the hormone brassinolide to young plants speeds up growth and maturation of several fruits and vegetables by as much as 2 to 4 weeks. In research trials, the steroid increased potato yields 24 percent; radish and lettuce yields, 15 to 30 percent, and bean and pepper yields, 6 to 7 percent. It also proved effective on soybeans. Once commercial companies develop large-scale methods for synthesizing brassinosteroids, their use could become commonplace.

APPLICATION OF A CHEMICAL BIOREGULATOR known as DCPTA to young soybean plants causes significant increases in oil and protein content of the soybean. In trials in California, soybean yields also increased by as much as one third.

COTTON PLANTS THAT NEED LESS WATER may result from genes borrowed from a drought-resistant cotton plant found growing wild in Mexico. The plant has a root system that carries more water up through the plant to leaf surfaces, and its leaf pores have a better mechanism for regulating the intake of airborne carbon and release of water.

A NEW CARROT known as 'A Plus' is a superior source of Vitamin A, packing 60 percent more carotene than varieties now on the market. The carrot also has good flavor. Several companies have begun limited production of the seed.

"SWEET SANDWICH" IS A NEW ONION that, unlike other onions, becomes milder in flavor while in storage at low temperatures. In commercial and home garden trials in New York State, the sweet onion outproduced 15 other varieties at 1,615 bushels per acre.

IMPORTANT PLANT BREEDING LINES have been released to public and private researchers...Three new kinds of soybeans, all noncommercial, have been developed by ARS and North Carolina State scientists. Breeders can use these germplasm lines to improve insect and nematode resistance in soybean cultivars being designed for use by farmers. They also can improve yields...Five sunflower germplasm sources with resistance to all four North American races of

rust have been released for use in sunflower breeding and hybrid seed programs by ARS and the North Dakota Agricultural Experiment Station...Three new kinds of sweet potatoes have been developed by ARS and university researchers in Texas and South Carolina...Eight new groups of winter-hardy alfalfa germplasm have been released by ARS and cooperating state agricultural experiment stations. All groups have desired multiple disease and insect resistance.

INVESTMENTS IN RESEARCH on wheat breeding by ARS and Purdue University have paid off by increasing wheat production in soft red winter wheat-growing regions by over 1 billion bushels since 1946.

GROUND WAS BROKEN MAY 19 for the new South Central Agricultural Research Laboratory, at Lane, Oklahoma. When completed, the laboratory will focus on production, harvesting, and marketing systems for horticultural crops important to the South Central region.

ANIMAL RESEARCH

A NEW BLOOD TEST proved over 90 percent accurate in detecting trichinosis in live pigs. A result of biotechnology research, the test delivers a higher level of accuracy than achieved before without slaughtering the animal.

RED BLOOD CELLS ENCAPSULATE DRUGS in a new slow-release system for prolonging the effectiveness of drugs in animals. Encapsulating a drug can potentially lower the required dosage and target it selectively to specific organs where it is needed. Animal systems are models for the human system.

A GOAT VIRUS DISCOVERY could shed light on the cause of rheumatoid arthritis in humans. Caprine arthritis-encephalitis (CAE) virus is the only virus proven to cause chronic arthritis in mammals. Now that the goat disease has been identified, it is being studied as an animal model for the human ailment.

LIVER SAMPLING FOR BIOPSY has been developed that permits removing large liver samples from live animals with little loss of blood. The procedure may find application in human medicine--possibly to stop bleeding of persons with livers damaged in serious accidents.

SKIN CANCER GROWTH IS INHIBITED by the use of an insect growth regulator, used routinely to control agricultural pests. In tests, diflubenzuron stopped the growth of malignant melanoma and skin carcinoma tumors in mice and reduced tumor size as much as 22 percent in one day.

RESTRICTING FEED DURING PREGNANCY affects progeny. Pigs from gilts in early-restricted diets had less backfat, less fat around the kidneys, smaller fat cells, and larger trimmed hams and loins than adequately fed gilts.

EARLY WARNING SIGNAL FOR ACUTE KIDNEY DYSFUNCTION can be obtained from the blood of sheep and swine. Animal red blood cells are interconnected by "bridges," which give advanced warning of kidney damage. The research raises the question of whether humans may exhibit these "bridges" at the onset of kidney failure, as well as during the progression of the disease. If proven applicable, these findings may be used as a quick diagnostic tool for early detection of diseased kidneys in humans.

NARROWLEAF SUMPWEED has been identified as almost certainly the cause of spring cattle abortions along the Eastern Seaboard from Nova Scotia to Texas. Although scientists have not yet demonstrated the cause-and-effect relationship between sumpweed and bovine abortions, they have shown that the weed causes changes in the reproductive systems of cattle. Livestock producers will benefit greatly by taking preventive measures.

RESOURCE AND ENVIRONMENTAL RESEARCH

STATE-OF-THE-ART TECHNOLOGIES--from computers to lasers to solar power--are being linked together to deliver automatically just enough water to thirsty plants. A fully equipped moving trickle-irrigation system also can apply herbicides, fertilizers, and mulch to plants as needed. Growers will be able to stretch the use of water, including slightly saline water, for irrigation.

"PAIRED-ROW" PLANTING, a new way of managing no-till small grains, when combined with deep banding of fertilizers, increases early growth of wheat and offers new possibilities for more efficient use of fertilizers and better control of weeds.

SLOT MULCHING VIRTUALLY HALTED SOIL EROSION in tests on winter wheat fields in the Palouse, exploiting the region's exceptionally abundant crop residues. The emerging conservation system relies on packing crop residues into slots dug 4 inches wide, 10 inches deep, and spaced 12 to 24 feet apart across the field's contour. The system enables runoff water to penetrate into frozen soil rather than washing it away. Residues keep the slot open and insulated throughout the region's typical freezing and thawing cycles.

A MOBILE UNIT THAT DETOXIFIES PESTICIDE WASTES on site simplifies the problems of safe disposal in remote areas where transportation is difficult or expensive. It combines use of high-energy ultraviolet light and oxygen to partially biodegrade such pesticides as 2,4-D, atrazine, and paraquat before the waste goes into disposal tanks. Much of the nation's groundwater that is contaminated by pesticide residues stems from a serious lack of disposal technology on farms, which typically rely on unlined pits to handle wastes.

A MOBILE SOIL-SAMPLING MACHINE has been developed that can extract in half a minute soil cores of various diameters and depths. Previous samplers took 10 minutes per core. Cores are used for soil chemical analysis, soil mapping, water content determination, root analysis, and other purposes.

A NEW WATER-MANAGEMENT STRATEGY has been developed so brackish water can be used to irrigate certain crops grown in rotation when they are in a tolerant stage. At other times and for sensitive crops in rotation, normal quality water is used. This strategy permits substantial conservation of valuable and limited water resources through re-use of waste water. Cyclic use of brackish water prevents the soil from becoming saline while permitting, over time, substitution of brackish water for better quality water for certain irrigations.

HUMAN NUTRITION RESEARCH

ZINC DEFICIENCY RETARDS BRAIN DEVELOPMENT in offspring of laboratory rats. Research showed that the hippocampus area of the brain of the zinc-deficient offspring was underdeveloped and low in zinc. This area of the brain normally has high concentrations of zinc, a trace mineral essential for the formation of nucleic acids and protein. Research implication: It might be prudent for pregnant women to consume foods rich in zinc, including oysters, the single best source, along with wheat germ, nuts, beef, turkey, and cheese.

FIRST ROOM-SIZE HUMAN METABOLIC CHAMBER has been built in Beltsville to monitor heat produced in the body during normal living. The unit will help explain why some people gain weight on diets that have little or no effect on other people. The chamber, called a calorimeter, also will be used to check the accuracy of existing calorie tables. Many of these tables are based on experiments that were conducted over 90 years ago.

DIET LOWERS CHOLESTEROL IN OLYMPIC ATHLETES when exercise would not hold down blood lipid levels. Research concludes that physically active people, who eat diets high in saturated fats, cannot rely solely on exercise to hold down their cholesterol levels. Switching athletes to a diet with three times more unsaturated than saturated fat lowered their cholesterol levels to normal.

A MORE PRECISE TECHNIQUE FOR MEASURING VITAMIN D and its 11 metabolites in the blood, milk and tissues has been discovered. The new technique replaces bioassay methods which are laborious and imprecise. Imbalances in vitamin D are implicated in rickets and osteomalacia, and other diseases affecting humans.

COMMERCIAL APPLICATION OF RESEARCH

GLASS REINFORCED COTTON CANVAS is being evaluated as a tent fabric with improved strength and flame retardant properties. Samples of the fabric have been sent to industry and commercial organizations in response to requests.

THE U.S. NAVY AND COTTON INDUSTRIES are working with ARS to develop fabric for cotton, flame retardant, easy-care garments for shipboard enlisted personnel. This research meets a need that became apparent when the British Navy encountered new weaponry in the Falkland Islands action.

SARA LEE'S RETAIL FOOD TECHNOLOGY DEPARTMENT expressed interest in an experimental evaluation of computer-formulated corn blends. They believe the program may have application in some of their food products.

NEW CLOTH which absorbs and releases four times more heat than ordinary fabric is of interest to Levi Straus. Another application of this material may be in building insulation and solar heated greenhouses.

A NEW SEWER SYSTEM will be put to practical use in eastern Ohio--the first area in the nation to construct a variable-grade gravity sewer (VGS). The VGS system cuts costs 40 - 50 percent, is virtually maintenance-free, compatible with existing sewer systems, and suitable for new urban developments as well as sparsely populated rural areas.

A NEW TEST to determine the shelf life of ground meats has been developed using commercially available equipment. The procedure, which measures lactic acid content, cuts testing time from 5 or 6 days to 1 hour.

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25 April 1984

Dr. O. H. Graham
USDA - ARS Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
MEXICO

Dear Hugh:

This week seems especially related to Tuxtla and screwworms. After mailing the letter to you yesterday, I arrived home and found my copy of the February 1984 issue of the J. Econ Entomology waiting for me. Of particular interest were the enclosed pages 267-270, "Simple technique for handling adults and collecting eggs of *Musca domestica*", Keymeulen & Gillard.

When first collecting eggs from houseflies, I used the common method of cotton soaked with a dilute milk media; then manually washed the eggs off the cotton. For ease of handling, I replaced the cotton with inert beads to facilitate a hydraulic recovery. Hence, the Keymeulen & Gillard technique was of interest. The various fly-egging techniques (house, olive, med, screwworm, tsetse, etc.) do share some similarities.

I also tried my method with the blowfly, but returned to fresh liver because the liver was as easy, and could be used to grow the larvae. For screwworm, I had assumed the method seen in 1983 at Tuxtla was acceptable, i.e. egg laying on a previously-used board in a heated dark room. However, the workers did use the precaution of long gloves and tape their arms to avoid skin contact with the screwworm eggs. As that was a dry recovery, I never knew whether a wet recovery was a disadvantage to subsequent use or the key factors developed by others.

If screwworm "egg lay-collection" warrents some work for reasons other than as a mechanical curiosity, than I would appreciate your comments. If doing something here, I would work from my own budget, use a local blowfly, and orient towards screwworm characteristics.

Sincerely yours,

W. G. Schultz

cc: R. Lowe/APHIS



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24 April 1984

Dr. O. H. Graham
USDA - ARS Screwworm Research
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
MEXICO

Dear Hugh:

Yesterday I received your letter of April 16th, and I found the information most interesting, i.e. the successes against the naturally occurring screwworm infestations over the past 15 months and the corresponding stability and quality of the sterile flies.

The copy of the memo by Drs. Novy and Cajero on the subject of heated vats for larval rearing was also very informative. As an interested novice at a distance of 3500-km, I will make a few comments because the heated-vat question relates to my 1983 visit and physico-chemical interests.

At the time of that visit, I understood the larval development was acceptable within the existing environmental gradients across the room. Proof of that acceptability has been the field successes over the past 15 months.

Within the room, there were two related but independent environments. One was the insect-rearing environment; the other was the human-work environment. The optimum for each was different, except possibly at the pupal stage which doubled as an informal rest area. Those insect and human needs could be further divided into chemical and physical. For the future, temperature-programable vats have potential benefits to the insects and could be introduced based on Mission and subsequent developments. But, would this provide a direct route to the primary question of human-work conditions, or would this result in a cascade of events and expenses throughout the system? Since the human-work conditions initiated the question, and the present insect rearing has been demonstrated as successful, should both be modified, or should just the human situation?

For the humans, there will still be the considerations of temperature, humidity, ammonia, and/or other factors, such as relative comfort due to air velocity. A supposition is that these environmental gradients would not necessarily need to be changed for the insects, but modification is primarily for humans. This modification may be visible (heated vats), or invisible (temp-humidity-velocity). Since comfort is relative, this may require visible changes (vats) in addition to the invisible changes (temp-humid) to satisfy the subjective human response.

24 April 1984

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There is good talent at Tuxtla within SARH and USDA, and perhaps this offers an opportunity for additional locally-developed information to help chart-a-course through the human and insect conditions --- from present to future. Or maybe, adequate physico-chemical information is already available on the rearing system.

As the emphasis is on humans, I am enclosing some reprints on relative comfort conditions [ASHRAE (1977) Fundamentals volume, F8.18 to 8.29]; the engineers at the admin building may have the ASHRAE set. The temperatures and humidities are obvious, but knowing the patterns are critical for both controlling the gradients within the room and for the re-design to human and insect needs. The air volumes and velocities are useful for controlling the body and eye comfort.

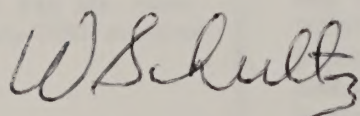
As a chemical check on nitrogen, sulfur, and carbon metabolites resulting from insects and microflora, three representative compounds are easy to check. The "ammonia" (or allied compounds) was particularly noticeable at the center of the main larval-growth room, due in part to the human-perception level of 53-ppm; this should be a prime indicator. Secondary indicators might be monoxide and sulfide. Carbon monoxide gives zero perception (odorless), hence a surprise potential for headaches and nausea, incipient or overt. Hydrogen sulfide has an initial perception of 3-ppm, but the sense-of-smell is readily fatigued by its presence. While it is useful to know the presence of these three representative compounds for judging circulation and makeup airs, it would be equally assuring to know that they are below the acceptance level.

For the overall chart, the existing temperatures-humidities could be combined with the various physical sources and parameters --- particularly the projected water-vapor pressure from the vats and resulting modification to latent-heat load on the air-conditioning system.

These various chemical and physical factors could be developed by using available materials and approaching it as a "paper" project. In fact, the emphasis should be on analyzing the system rather than data gathering. Supplies could be held to less than US \$1000. The main expense would be about 0.3-SY to measure, analyze the data, and present in a useful report. From this perspective, I believe this would be useful to the design and operation of the system.

With best wishes, and

Sincerely yours,



W. G. Schultz

cc: R. Lowe/APHIS

Simple Technique for Handling Adults and Collecting Eggs of *Musca domestica* (Diptera: Muscidae) and *Aleochara bilineata* (Coleoptera: Staphylinidae)

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J. Econ. Entomol. 77: 267-270 (1984)

ABSTRACT A simple oviposition device, containing inert, expanded, clay granules, has been developed for both the house fly, *Musca domestica* L., and the staphylinid beetle, *Aleochara bilineata* Gyllenhal. For the house fly and the *Aleochara* beetles, the optimum particle size of the granules is 2.0 to 2.8 mm and 1.0 to 2.0 mm, respectively. A quick method for extracting the eggs of both species from the oviposition medium, by washing, is also described.

THE HOUSE FLY, *Musca domestica* L., is maintained in many laboratories for various kinds of biological investigations. Consequently, descriptions of a variety of rearing techniques, rearing media, and equipment have been published (West and Peters 1973). House fly eggs are generally laid on oviposition substrates, such as cottonwool pads, cotton rolls, muslin, or filter paper. These substrates are soaked in either sour or diluted milk, or in a solution of milk powder and ammonium carbonate in water with or without yeast (Basden 1947, Wilkes et al. 1948, Anonymous 1956, Keiding and Arevad 1964, Spiller 1966, Ashby 1972, Singh and Jerram 1976). Oviposition can also be induced in petri dishes containing fermenting larval media (Knipe and Frings 1953). The separation of eggs from such oviposition sites is generally time consuming.

In our laboratory, where house flies are reared for release-recapture experiments, a quick and reliable technique for collecting house fly eggs is an essential requirement. In this article, we describe such a technique using expanded clay granules as the oviposition substrate. Moreover, this technique is also suitable for collecting eggs of *Aleochara bilineata* Gyllenhal, an important beetle predator and parasite of several dipterous pests of vegetable crops. The beetle-rearing methods as described by Fuldner (1960), Adashkevich and Perekrest (1977), and Bromand (1980), are cumbersome and only suitable for the production of a restricted number of beetles. The bottlenecks in these rearing procedures are the oviposition substrate and the collection of the eggs. The rearing method developed in our laboratory solves these problems.

Materials and Methods

Adult Cage and Oviposition Device for the House Fly. The adult cage consists of a cylinder of nylon gauze (diameter, 25 cm; height, 50 cm; 1.2-mm mesh) fastened at the top and bottom (Fig.

1B). The top and bottom of the cage are made of wood (1.5 cm thick; 25 cm in diameter). In the top of the cage, 25 holes are drilled, each containing rubber stoppers holding thin glass tubes (height = 10 cm; diameter = 0.5 cm) (Fig. 1A). The 25 glass tubes, filled with sugar water, provide a sufficient drinking surface for the flies. Every 4 days, the tube holder is renewed.

Two openings are made in the bottom of the cage (Fig. 1B). One contains a Plexiglas box (6 by 13 by 1 cm) held in place by three clips (Fig. 1C). In this box, a mixture of 50 g of milk powder, 50 g of sugar, and 10 g of yeast autolysate with 0.1% cholesterol (Spiller 1966) is provided as food for the adult flies. This food is replaced every 2 to 3 days. A nylon gauze (1.8-mm mesh), glued onto a Plexiglas frame (7 by 14 by 1 cm), is used to cover the adult food inside the cage (Fig. 1C, parts 4 and 5). The frame is placed in a recess in the base of the cage. The flies are supported by this gauze as they feed, and the gauze also prevents flies from escaping when the food is replenished. Louw (1964) has shown that both a large feeding area and a thin layer of food are necessary for sufficient fecundity and fertility.

The oviposition site consists of a Plexiglas box (7 by 7 by 2 cm) filled with expanded clay granules (Argex, Argex-Sicalex N.V., Kraainem, Belgium) (2.0-2.8 mm in diameter), soaked in a mixture of 5 g of milk powder, 5 g of yeast, 5 ml of saturated solution of ammonium carbonate, and 320 ml of water (Singh and Jerram 1976). The oviposition box is held under the second opening in the bottom of the cage by three clips (Fig. 1D). The oviposition box is attached in the late afternoon, and the eggs are collected the next morning. Flies, influenced by these granular oviposition stimulants, lay their eggs through a nylon mesh gauze (1.8 mm), similar to the gauze covering the adjacent feeding site (Fig. 1D, parts 4 and 5). Provided that the clay granules of the oviposition site are held close to the gauze cover, the gauze does

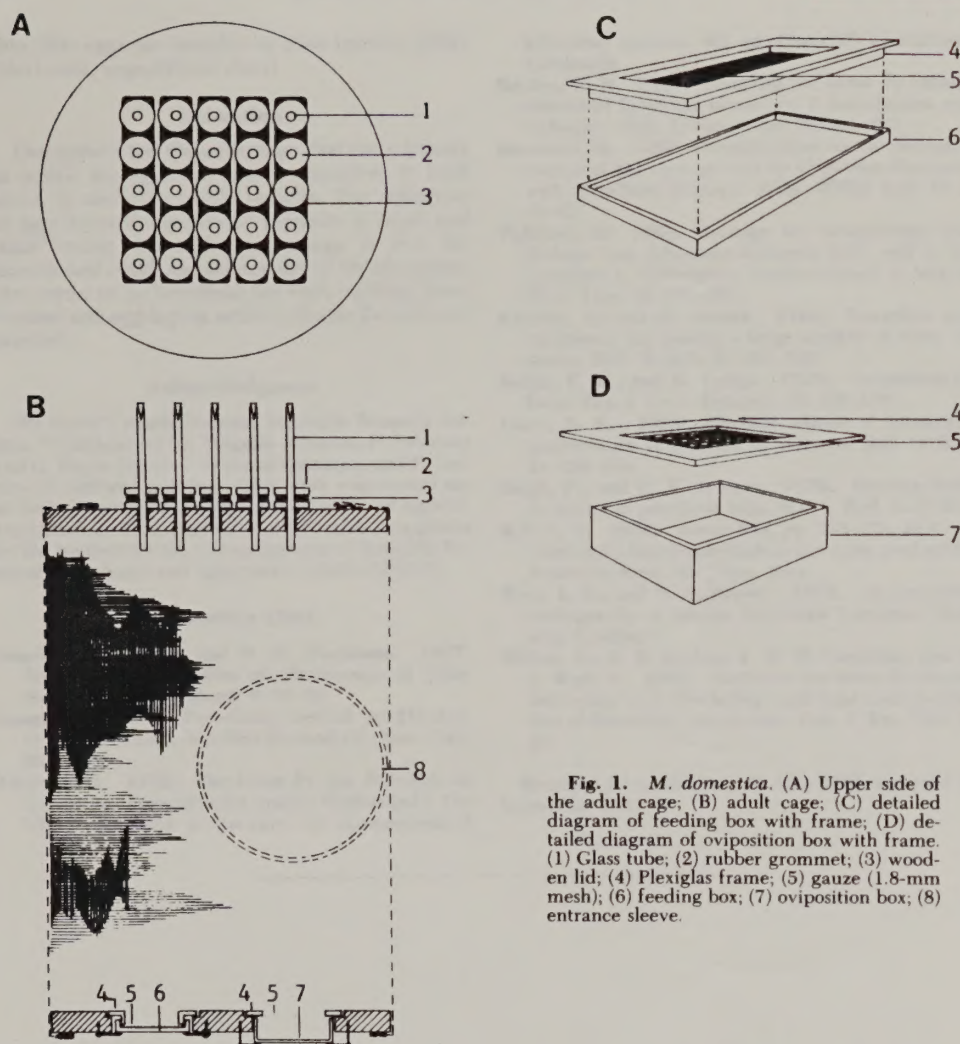


Fig. 1. *M. domestica*. (A) Upper side of the adult cage; (B) adult cage; (C) detailed diagram of feeding box with frame; (D) detailed diagram of oviposition box with frame. (1) Glass tube; (2) rubber grommet; (3) wooden lid; (4) Plexiglas frame; (5) gauze (1.8-mm mesh); (6) feeding box; (7) oviposition box; (8) entrance sleeve.

not influence oviposition. For experiments where only a restricted number of flies are used (e.g., small cages), cups or bottles filled with clay granules soaked in the egg-laying solution can be used as oviposition sites.

Collecting House Fly Eggs. To gather eggs, the oviposition box is filled with water and left for a maximum of 10 min to separate most of the egg clusters into individual eggs. The clay granules are then poured into a small sieve which rests on a second sieve (diameter = 10 cm). The top sieve (1.8- to 2.0-mm mesh) retains the clay granules and any remaining egg clusters. The sieve is then washed with a gentle stream of tap water for about 1 min, ensuring that the remaining eggs are sep-

arated and washed into the bottom sieve (0.3-mm mesh). These eggs are transferred to a gauze-bottomed plastic tube. After centrifugation, the collected eggs are weighed on an analytical balance (Van Keymeulen, unpublished data).

Cage and Oviposition Device for *Aleochara bilineata*. Our laboratory experiments have demonstrated that the presence of crevices in which the female *Aleochara bilineata* can retire, stimulates beetle oviposition. It has been shown that if beetles can retire under a simple blotting paper or in a substrate of expanded clay granules, their fecundity is doubled (200 eggs per female) compared with that of beetles without any such resting places (100 eggs per female) (Hertveldt, unpub-

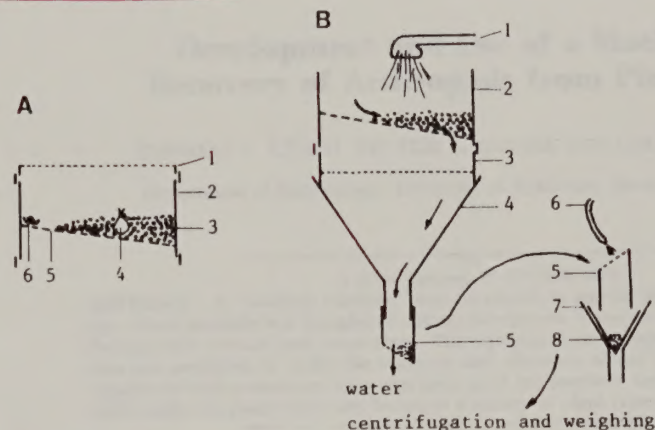


Fig. 2. *A. bilineata*. (A) Adult and oviposition cage: (1) top ring with fine nylon gauze; (2) Plexiglas cage; (3) expanded clay granules; (4) gauze bag with host pupae; (5) nylon gauze (750- μ m mesh); (6) food. (B) Egg collection method: (1) bath sprayer; (2) oviposition cage; (3) ring with nylon gauze (470- μ m mesh); (4) funnel; (5) plastic tube and eggs; (6) siphon; (7) funnel; (8) filter paper and eggs.

lished data). The presence of host pupae in a substrate of expanded clay granules also doubles beetle fecundity (400 to 500 eggs per female). The influence of the host plant (e.g., rutabaga pieces) on beetle fecundity is not clear.

The fecundity of the beetles is influenced by the pores and the moisture content of the substrate, both variables being determined by the particle size of the granules (Hertveldt, unpublished data). Therefore, expanded clay granules with particle sizes of 1 mm, 1 to 2 mm, 2 to 3 mm, and >3 mm were tested to find the optimum particle size. Although pores between clay granules of 1 mm were too narrow and the moisture content of the substrate was too high after washing the eggs (cf. collection method), the pore size from granules greater than 2 mm, was found to be too wide, and the moisture content too low, 2 days after washing out the eggs. In both cases, fecundity was only 70% of that expected. In cages with granules >3 mm, fewer eggs hatched, probably due to the low moisture content of the substrate. Based on these results, expanded clay granules of 1 to 2 mm were chosen for the further development of the adult cage and of the oviposition device.

The adult cage (Fig. 2A, part 2) consists of a Plexiglas cylinder (21 cm in diameter by 7 cm). A top ring 5 mm deep and covered with a fine nylon gauze is placed on the cylinder. Another ring, covered with a nylon gauze of 750- μ m mesh, is glued inside the cylinder at an angle of 45° (beetles can pass through a gauze with a mesh of 800 μ m). On the lower half of this ring, expanded clay granules are placed to cover half of the cage bottom. The granule layer functions both as a resting place for adults and as an oviposition substrate. Adults feed ad lib. on minced meat or fly larvae. A gauze bag enclosing the cabbage root fly, *Delia brassicae* Bouché, or onion fly, *Delia antiqua* Meigen, pupae is placed among the clay granules as an oviposition stimulant. Nearly all of the eggs are laid in the

clay substrate. The adult beetles are kept at 22 to 24°C and 60% RH under constant dim light. Since, under these conditions, embryonic development takes about 5 days, eggs have to be collected twice a week. After each use, clay granules are washed and dry sterilized.

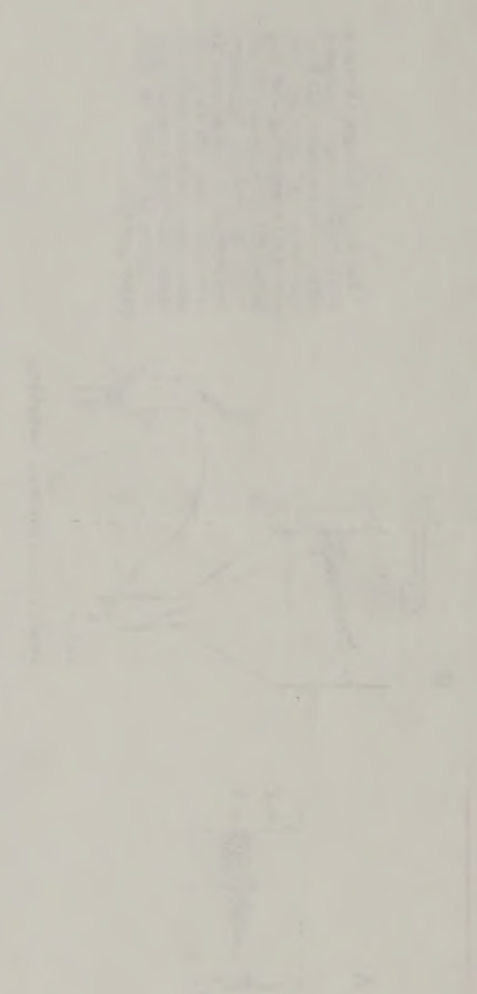
Collecting *A. bilineata* Eggs. The adult cage is placed onto a Plexiglas cylinder possessing a bottom nylon screen of 470- μ m mesh (Fig. 2B). The two cylinders are then placed on a funnel. A plastic tube with a sloping bottom is then slipped over the stem of the funnel. The bottom of this tube is covered with a fine nylon gauze of 200- μ m mesh to collect the eggs. The adult cage is then washed with a gentle stream of lukewarm tap water (maximum 1–2 liters). While pieces of elytra and cuticle from dead beetles pass easily through the bottom sieve of the cages and are retained on the 470- μ m mesh screen below, the *Aleochara* eggs pass through. As the number of eggs collected in the plastic tube is estimated by weight, any errors due to impurities must be minimized.

After spraying water for ca. 25 sec, ca. 99% of the eggs are found on the bottom of the plastic tube. This fact was demonstrated by spraying the oviposition substrate during 5, 15, 25, 35, and 45 sec. The numbers of eggs retained in the granules were measured by counting the eclosed larvae, 6 days after washing. In accordance with the spraying times described above, 15, 5, 1, 2, and 1% of the larvae were counted relative to the number of collected eggs (Hertveldt, unpublished data). The tube is then removed from the funnel stem, and the eggs are siphoned onto filter paper. After centrifugation for 4 min at 820 $\times$ g and drying for 2 min, the eggs are weighed on an analytical balance. Previously, beetle eggs were dry and were hand collected in our laboratory. Experiments, however, have demonstrated that spraying the adult beetles two or three times a week does not affect their mean longevity (70 days), their fecun-

The first part of the paper is devoted to a discussion of the general principles of the theory of the structure of the crystal lattice. It is shown that the structure of the crystal lattice is determined by the balance of the forces of attraction and repulsion between the atoms. The forces of attraction are due to the electrostatic interaction between the positive and negative ions, while the forces of repulsion are due to the overlap of the electron shells of the atoms. The balance of these forces leads to the formation of a regular, periodic arrangement of the atoms in the crystal lattice.

The second part of the paper is devoted to a discussion of the properties of the crystal lattice. It is shown that the properties of the crystal lattice are determined by the structure of the crystal lattice. The properties of the crystal lattice include the density, the refractive index, the thermal conductivity, and the electrical conductivity. The properties of the crystal lattice are also determined by the temperature and the pressure.

The third part of the paper is devoted to a discussion of the methods of the study of the structure of the crystal lattice. It is shown that the structure of the crystal lattice can be studied by a variety of methods, including X-ray diffraction, electron diffraction, and neutron diffraction. The structure of the crystal lattice can also be studied by the method of the measurement of the density, the refractive index, the thermal conductivity, and the electrical conductivity.



The fourth part of the paper is devoted to a discussion of the applications of the theory of the structure of the crystal lattice. It is shown that the theory of the structure of the crystal lattice has many important applications in the fields of physics, chemistry, and materials science. The theory of the structure of the crystal lattice is used to explain the properties of the crystal lattice, to predict the properties of new materials, and to design new materials.

The fifth part of the paper is devoted to a discussion of the conclusions of the paper. It is shown that the theory of the structure of the crystal lattice is a very important and useful theory. The theory of the structure of the crystal lattice has many important applications in the fields of physics, chemistry, and materials science.



dity (300 eggs per female), or their fertility (80%) (Hertveldt, unpublished data).

Discussion

Our system has the advantage that the substrate in which the eggs are laid is attractive to both house fly and rove beetle females. The collection of eggs from the expanded granules is rapid and labor saving. An added advantage is that the smooth and rough surface texture of the clay granules seems to be beneficial for both walking (rove beetles) and egg-laying activity (house fly and rove beetles).

Acknowledgment

We thank S. Finch, National Vegetable Research Station, Wellesbourne, for valuable criticism, P. Pelerents and G. Buysse for their technical assistance, and F. Shapiro for editorial assistance. This work was carried out at the Laboratory of Zoology of the Faculty of Agricultural Sciences, State University of Ghent, and supported by the Institute for the Encouragement of Scientific Research in Industry and Agriculture (IRSIA-IWONL).

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Development and Use of a Machine for Recovery of Arthropods from Plant Leaves

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ABSTRACT A "washing machine" was developed to recover spider mites, *Tetranychus* spp., from multiple-leaf samples of cotton, *Gossypium hirsutum* L., and procedures were developed to recover and count them. The equipment and procedures are described, and data are presented to verify the accuracy and efficiency of our leaf wash technique. The equipment and procedures have also been used for recovery and counting of insects and spider mites on grain heads and leaves of a variety of plant types.

RELIABLE ESTIMATES of pest and beneficial arthropods are an essential element in the management of pest arthropods. For many insect and spider mite pests, direct counts of the developmental stages are made on foliage with the aid of magnification. Worker fatigue when using this method to count spider mites can result in much counting error. Smith and Little (1954) developed a leaf punch that enabled random or selective removal of portions of plant leaves on which spider mites were counted. This method was subject to individual bias that could lead to major differences in sampling results. A brushing machine was developed by Henderson and McBurnie (1954) that removed the mite stages from foliage and deposited them on a glass plate for later counting under a microscope. Although this method has worked well in many instances, the leaves of some plants such as cotton may be torn by the machine or may fold during the brushing process, and some mites may not be removed. In addition, when leaves have dust deposits, this dust is also transferred to the glass plate, where it may interfere with counting.

Harvey (1954) developed a centrifuge technique that recovered a proportion of the spider mite population from wheat, but did not provide a full measure of the stages, particularly eggs and molting forms. Jones and Prendergast (1937), and later Henderson (1960), developed leaf-washing methods for recovery of spider mites from foliage, citrus fruits, and soil.

We have used direct counts, brushing machines, and the washing procedures developed by Andres (1957). The method of Andres, that of washing leaves in a sodium hypochlorite solution in 2-quart (ca. 1.9-liter), wide-mouth Mason jars and recovering the spider mite stages on filter paper, was more satisfactory than the others, but dust from the leaves often interfered with locating and counting the mites, particularly the egg stage. When kerosene was added to this solution after the leaves had been removed, and the jar contents were agitated vigorously, the spider mites were separated into the kerosene, and the dirt was left in the water

phase. However, the procedure was slow and would accommodate only 10 cotton leaves per sample. Although each method has utility under particular circumstances, all are tedious and subject to counting error.

We developed a leaf-washing process similar to that of Scriven and McMurtry (1971) which enabled us to handle numerous samples per day. This method provided a high degree of mite recovery, free of dirt and sand. Described herein is a leaf-washing machine and how it is used for spider mite removal and recovery. A modification for a Buchner funnel to improve spider mite recovery is also described, as is our counting procedure.

Materials and Methods

Leaf-Washing Machine. The leaf-washing machine (Fig. 1) consists of a washing tank with two water solution inflow jets that create a rolling motion to the washing solution, an additional inlet that provides flushing action, flow rate control valves, an outflow pipe through which the spider mites are carried into sieves by solution flow, a basin that catches the solution after the mites are removed through the series of sieves, and a pump (not pictured) which returns the washing solution from the catch basin to the washing tank through the jets. The washing tank is constructed from a 20-cm length of 30.5-cm-diameter polyvinyl chloride (PVC) irrigation pipe. The cut ends of the irrigation pipe are closed with PVC caps constructed for use with this pipe. A hole (22 by 13 cm) is cut into the top for filling with solution and for introduction and removal of the plant leaves. This tank is fastened by means of steel straps to two supports made of 40-cm lengths (6 by 12 cm) of wood, notched to form a saddle. A 6.35-cm hole cut in one cap, with the lower edge positioned 5.7 cm below the access opening, is fitted with a 15-cm length of 6.0-cm-diameter PVC irrigation pipe which is "glued" into this hole flush with the inner tank surface to provide a drain spout from the tank. A 1-cm hole, drilled in the opposite end of

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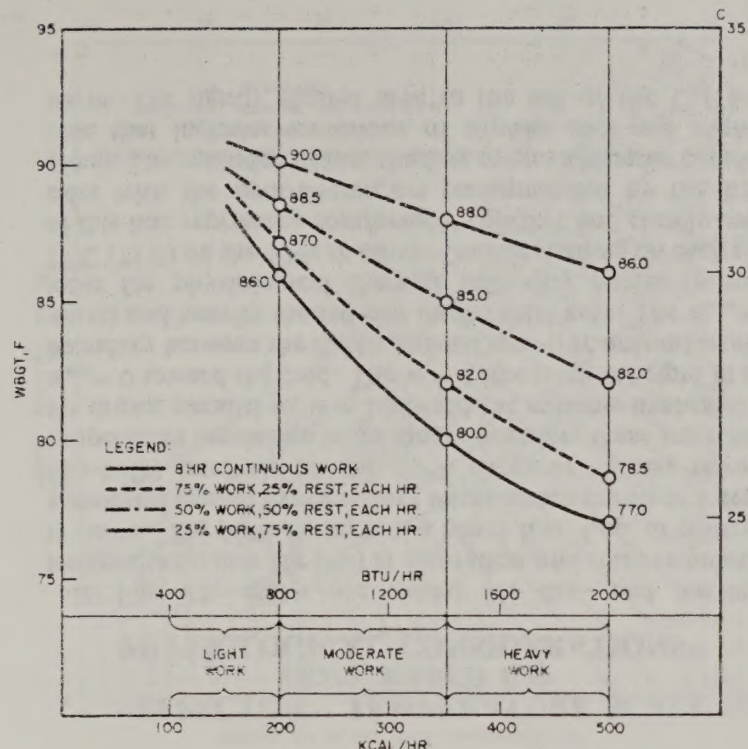


Fig. 13 Permissible Heat Exposure Limits Predicted by the WBGT Index^{4,61}

The original t_{eff} was developed for subjects wearing 1 clo insulation. Humid Operative Temperature t_{oh} for a subject wearing 1 clo coincides very closely with the ASHRAE T_{eff} scale when regulating by sweating. For wettedness factors, $<0.4 t_{oh}$ may be used as a rational replacement for t_{eff} , and serves as a basis for correcting the original t_{eff} for lower clo values used today.

Black Globe Temperature (t_g).⁵⁹ The equilibrium temperature of a 152.4-mm (6-in.) diameter black globe has been used as a single temperature index describing the combined physical effect of dry-bulb temperature, air movement, and radiant heat received from various surrounding areas. For sources radiating at low temperature (<1000 K), black and skin-colored globes respond in the same way to radiant heat.⁴⁵ The globe temperature is now usually used as a simple device to determine the mean radiant temperature (see Chapter 13). Also see Eq 58, below, which shows how a globe may be used to measure ERF for comfort.

Corrected Effective Temperature (CET).⁵⁹ Black globe temperature is substituted for the dry-bulb temperature of the original Effective Temperature Scale, to correct for effects of any intense radiant heat source in the surrounding environment. The globe temperature is a measure of the operative temperature in an enclosed space in which comfort may be maintained by radiant heat.

Wet-Bulb Globe Temperature (WBGT) Index.⁶⁰ Used as a weighted average of the dry-bulb, a naturally convected wet-bulb, and globe temperature according to the relation:⁵⁷

$$WBGT = 0.7t_{wb} + 0.2t_g + 0.1t_{db} \quad (51)$$

This index includes the combined effect of low temperature radiant heat, solar radiation and air movement. Eq 51 should be used in the presence of solar radiation. In enclosed environments, the t_g term is dropped, and the weighting factors

for t_{db} and t_{wb} are now 0.15 and 0.85, respectively. Air movement affects both t_{wb} and t_g ; its effect is thus indicated in the index. The relation⁶¹ between WBGT temperatures and permissible heat exposure limits is illustrated in Fig. 13.

The WBGT, theoretically related to t_{oh} and to the older ASHRAE t_{eff} , can be derived rationally if an accurate relationship between t_{wb} (natural), t_a , and t_{dew} is known. Weighting coefficients used here are useful for predicting tolerance limits to heat only, rather than for comfort.

Wind Chill Index (WCI).⁶² An empirical equation developed in Antarctica in 1948 by Paul Siple for the U.S. Army. The index describes rate of heat loss from a litre cylinder of water at 33°C (91.4 F) as a function of ambient temperature and wind velocity. As given originally:

$$WCI = (10.45 + 10\sqrt{V} - V)(33 - t_a) \text{ in kcal/m}^2 \cdot h \quad (52)$$

where V and t_a are metres/sec and degree Celsius.

There have been a number of valid objections to Siple's formulation and to basic data from which it was derived. WCI is not an accurate measure of body heat loss. The index predicted by this formula approaches a peak value at a 90 km/h (56 mph) wind speed, then decreases with increasing wind velocity. However, for wind velocities below 80 km/h (50 mph), this index has provided a reliable way of expressing combined effects of wind and temperature on subjective discomfort, and has proven useful for ordering the relative severity of the environment. Furthermore, if the calculated (WCI) is less than 1400, and actual air temperature is above -10°C (-14°F), there probably will be little risk of frostbite during brief exposures (30 min or less), even for bare skin.

Rather than express wind chill level as a numerical index, common practice has been to use the corresponding *equivalent wind chill temperature*, the ambient temperature which, in a calm, i.e., 6.4 km/h (4 mph) wind velocity, would yield the same WCI. Equivalent wind chill temperature (t_{eq}) may be readily calculated by:

$$t_{eq} = -0.04544(WCI) + 33 \text{ for } ^\circ\text{C} \quad (53)$$

This relation does not imply cooling below ambient temperature, regardless of wind velocity or wind chill. Instead, cooling is toward ambient temperature, at a rate as if cooling were to the lower *equivalent wind chill temperature*. Since wind accelerates rate of heat loss, a man exposed will feel as if exposed to the lower *equivalent* temperature, while in reality his surface is cooling faster toward the ambient temperature.

COMPARISON OF HUMID OPERATIVE TEMPERATURE, LINES OF CONSTANT WETTEDNESS, COMFORT, AND TOLERANCE

On a psychrometric chart with vapor pressure on the ordinate and dry-bulb temperature on the abscissa, lines of constant t_{oh} and constant w_{rsW} are drawn (Fig. 14). Up to values of $w_{rsW} = 0.4$, the trends of these two types of loci are essentially parallel to each other. Also plotted are the latest curves reported by KSU for *slightly cool*, *comfortable* (i.e., neutral), and *slightly warm*, for 1-hr exposure.⁴³ The t_{oh} lines are similar to the old ASHRAE Effective Temperature Scale, if corrected for 0.6 clo. KSU *comfort* lines, described below, fall close to the $w_{rsW} = 0$ line or where physiological thermal neutrality occurs. Above a $w_{rsW} = 0.5$ line, the flatter slopes for the wettedness lines reflect the increasing importance of humidity.

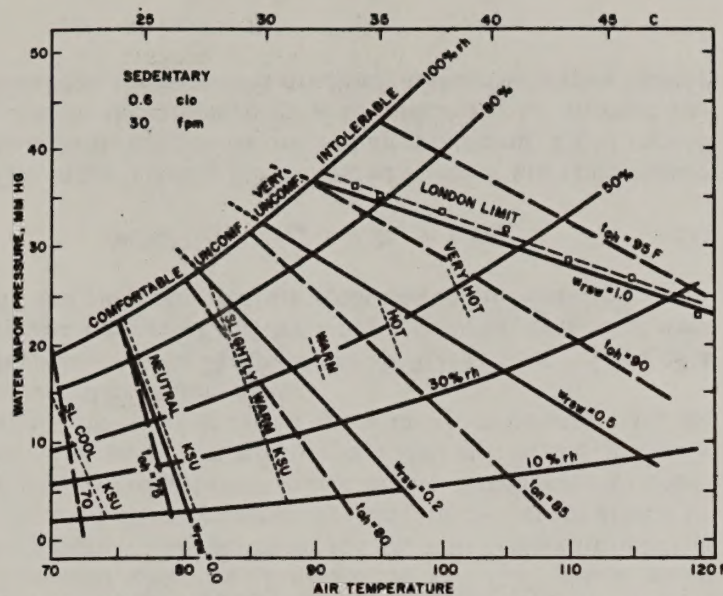


Fig. 14 Loci of Constant Humid Operative Temperature and Constant Wettedness Compared with KSU Measurement of Temperature Sensation, Pierce Laboratory Observations of Warm Discomfort, and the London Limit for Heat Tolerance

In the cold, temperature sensation, skin temperature, and ambient air temperature are all closely related to cold discomfort; and all are associated with increased vasoconstriction, with the possible initiation of shivering or with such behavioral regulation as exercising or using more clothing.

At the warm extreme, the *London* limit,⁵⁴ the upper working limit for *fit* young healthy men, has been plotted. This curve falls very near the 100% wettedness line, although clothing and activity levels may have been different from the sedentary (0.6 clo) plotted.

The 100% limit for an unclothed subject is very close to the upper limit for a clothed subject. Low exercise levels will not change this limit significantly, since higher metabolic levels and increased sweating rates are matched by greater values for E_{max} , a result of the higher evaporative heat transfer coefficient due to increased air movement with exercise.

"EFFECTIVE" TEMPERATURE SCALE (ET*) BASED ON PHYSIOLOGICAL CONSIDERATIONS⁶³

In Fig. 15, scales are traced for dry- and wet-bulb temperatures, mm Hg (Pa) at saturation, and relative humidity curves. The 50% rh curve is a heavy line. Loci of constant wettedness caused by regulatory sweating are drawn at 5 deg F (dry-bulb) intervals on this 50% rh curve. Where normal temperature regulation is no longer possible, these scale lines are drawn parallel to $w = 1$ toward the extreme heat, and to $w_{rs} = 0$ toward the cold. The $w = 1$ line is on the right at the boundary between the lightly shaded area (for uncomfortable warm) and heavily shaded (for intolerable) area. The $w_{rs} = 0$ locus for physiological thermal neutrality passes through 25°C (77 F) on the 50% rh curve. Double shading on each side of this line represents *comfortable comfort* and closely coincides with the *neutral-comfort* recommended by the KSU group. The extended lighter shading covers a broader comfort zone that includes sensations of *slightly cool* and *slightly warm*. The lightly shaded area to the left of the C (56 F)

locus represents the beginning of an *uncomfortably cold* zone. Shaded areas on the right represent conditions rated *uncomfortably warm*. The heavily shaded area means *tolerable only for limited periods of exposure*. These various loci, as drawn, represent the proposed new Effective Temperature Scale ET*.

The ET*, classed as a rationally derived index, has no physical meaning in the heat balance equation between man and his environment. In contrast, humid operative temperature t_{oh} does have a significant use in a heat balance equation.

The use of ET* as a comfort health index is described in Figs. 16 and 22.

In the past, custom has been to name the numerical value of an *effective temperature* scale where the loci for constant sensation or heat stress intersect the 100% rh line. Temperatures on the 50% rh line have been chosen for the ET* numerical index as these values are more easily associated with environments of everyday living. The probable average humidity may be considered 50%. For the 100% rh line, the complete range of thermoregulation covers approximately 24 to 27°C (75 to 80 F), a numerical range currently used in the earlier ASHRAE Effective Temperature Scale. On the 50% curve, the same range extends approximately 25 to 41°C (77 to 106 F). Above and below the outer limits of regulation, the change in new *Effective Temperature* on the new scale will more closely follow the dry-bulb temperature toward the cold, and the wet-bulb for the extreme heat.

Using the intersection of the loci of constant skin wettedness with the dry-bulb 50% rh curve, the numerical range for Effective Temperature over the zone of temperature regulation by sweating is doubled. Above and below this range ($w_{rsw} \sim 0$ to 1.0), the new scale parallels dry-bulb. In the cold, the scale temperature is approximately 0.5 °C (1 deg F) below dry-bulb. In the hot intolerable range, it is consistently 9°C (16 Deg F) above dry-bulb.

PREDICTION OF THERMAL COMFORT

This section covers effects on comfort of: (1) variations in humidity for the common case of $DBT = MRT$ and low air movements; (2) variation in air movement and MRT at normal humidities; and (3) high temperature radiant heat.

Historical Perspective

ASHRAE has supported research on thermal comfort for more than 50 years. The original Effective Temperature Scale (Houghton and Yaglou, 1923)⁶⁴ is still often used by physiologists and engineers as the standard in measuring comfort, although its shortcomings (overexaggeration of humidity at lower temperatures and underestimation of humidity at heat tolerance levels) were recognized by Yaglou⁶⁵ as early as 1947. In 1961, Nevins⁶⁶ showed that temperature criteria for thermal comfort have risen steadily since 1900, from 18 to 21°C (65 to 70 F) DBT range to 24 to 26°C (75 to 78 F) DBT range in 1960. Effective temperature for comfort increased from 18 °C (64 F) ET in 1923 to 20 °C (68 F) ET in 1941. This increasing trend probably results from year-round use of lighter-weight clothing and from changing living patterns, diets, and *comfort* expectations.

In the 1950's, ASHRAE decided to reevaluate its Effective Temperature Scale. Studies of Koch et al in 1960⁶⁷ showed humidity had negligible effect on comfort until 60% rh and 65 F (18°C) dry-bulb were reached. Below these levels, dry-bulb temperature alone was the governing factor. In 1966, Nevins

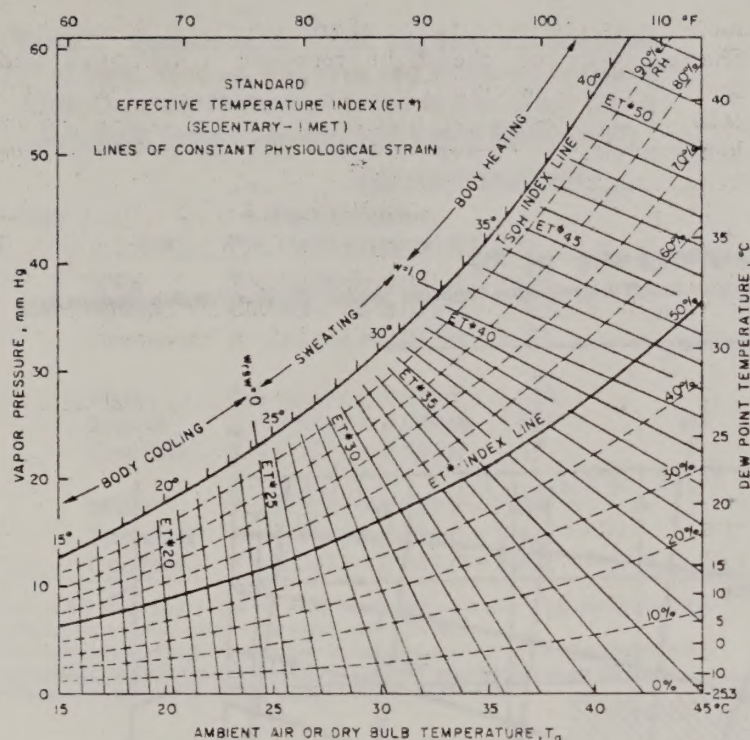


Fig. 15 Effective Temperature (ET*) Scale
Based on Loci of Constant Wettedness
Caused by Regulatory Sweating

et al⁴³ extended this study for ASHRAE. Using 720 subjects wearing similar light clothing, they obtained high statistical validity. Their new *comfort line* as affected by humidity proved to be between the earlier data of Houghton⁶⁴ and of Koch.⁶⁷ Since 1956, comfort limits selected for field application have usually been expressed in terms of dry-bulb and wet-bulb temperatures. The original Effective Temperature Scale is still used on a numerical basis for predicting extreme discomfort from high temperatures and humidities and man's heat tolerance while working at high humidities.^{52,54} But since 1956, it has seldom been used to specify *comfort* conditions.

The early success of the Effective Temperature Scale stimulated new research to establish a rational physiological and physical basis for it.

Winslow et al⁶⁸ introduced the category scale of *pleasantness-unpleasantness* in contrast to the *warm-comfortable-cool* scale of Yaglou and Houghton. More recently, physiologists have recognized that sensations of comfort and of temperature may have different physiological and physical bases, and each should be considered separately. This dichotomy was recognized in ASHRAE Comfort Standard 55-74, where thermal comfort is defined as "that state of mind which expresses satisfaction with the thermal environment." Unfortunately, little practical research to date specifically fulfills this definition. Most current predictive charts are based on comfort defined as "a sensation that is neither slightly warm nor slightly cool."

ASHRAE Research has usually been limited to *sedentary* man, lightly clothed. This approach is sound, since about 90% of man's indoor occupation and leisure time is spent at or near the *sedentary* activity level. Predictive methods described below are believed accurate within stated limitations. During physical activity, a change occurs in man's physiology. Physiological thermal neutrality in the older (sedentary) sense does not exist. Some form of thermal regulation always occurs within man's body during exercise.

Temperature and comfort during activity^{58,69,70} have different bases than during the sedentary condition. Sedentary skin and body temperatures used as indices of comfort, will likely prove false during moderate to heavy activity.

The KSU-ASHRAE Comfort Studies

The Institute for Environmental Research at Kansas State University under ASHRAE contracts, has conducted extensive research since 1963 on thermal comfort of clothed sedentary subjects. Studies^{71,72} on 1600 college-age students revealed statistical correlations among comfort level, temperature, humidity, sex, and length of exposure. Groups of five men and five women were exposed to 20 DBT's ranging from 15.6 to 36.7°C (60 to 98 F) in increments of 1.1 °C (2 deg F) at each of eight rh's: 15, 25, 35, 45, 55, 65, 75, and 85%. The MRT was equal to DBT, and air velocity was <0.17 m/s (35 fpm). After one hour and every half hour thereafter up to 3 hr, subjects reported their thermal sensations on a seven category ballot in which:

- + 3 = hot
- + 2 = warm
- + 1 = slightly warm
- 0 = comfortable
- 1 = slightly cool
- 2 = cool
- 3 = cold

Results showed that, for sedentary subjects dressed in standard clothing with a thermal resistance of about 0.6 clo after an exposure of 3 h, one or more subjects voted *comfortable* over a DBT range of from 16.7 to 36.6 °C (62 to 98 F) with a mean of 26°C (79 F), and rh of 50%. It was also found men feel warmer than women during their first hour at a given temperature and humidity, while playing a minor role, is more significant in determining how men feel than how women feel. The Equations from this study for predicting thermal sensations from dry-bulb temperature and atmospheric water vapor pressure for men and women for different exposure periods are presented in Table 7. Vapor pressure is the primary humidity variable describing the physics and physiology of evaporative heat loss; it, rather than conventional rh was used in these regression equations. Plotting the regression equation results in sets of observed lines of *equal thermal sensation* for lightly clothed sedentary young adults.

In a further analysis, data was treated with a newly developed procedure known as a spline analysis.⁷³ From this, three equations were developed for predicting the thermal sensation from the new ET*:

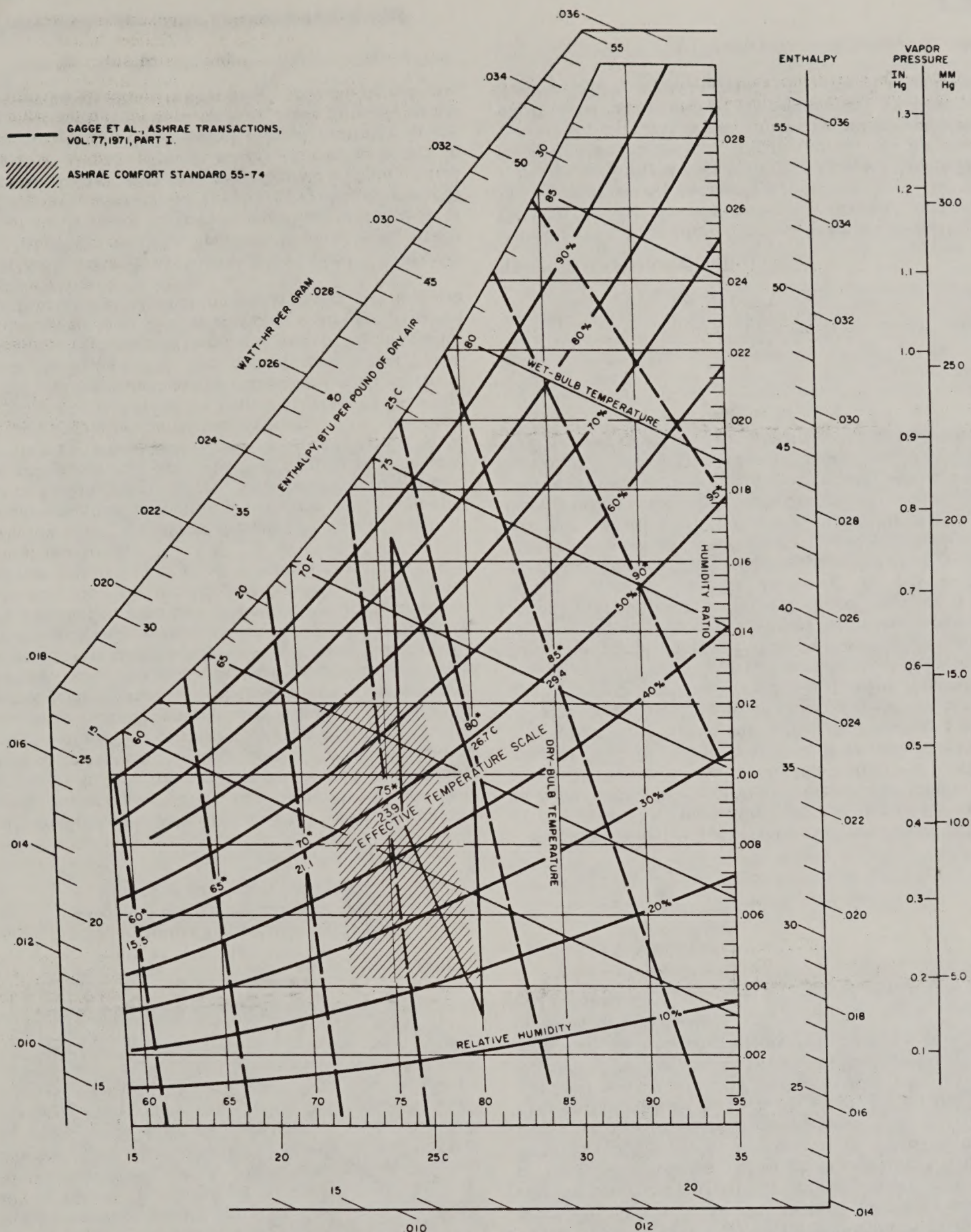
Temperature
Range (ET*)

$$\begin{aligned} >31.5 & Y = 0.104 ET^* + 2.556 & (54) \\ 20 \text{ to } 26.5 & Y = 0.326 ET^* - 4.487 & (55) \\ <20 & Y = 0.160 ET^* - 1.034 & (56) \end{aligned}$$

The New ASHRAE Comfort Chart

In Fig. 16, the comfort zone recommended in ASHRAE Comfort Standard 55-74 is shown. The new ET* lines from Fig. 15 are drawn over the comfort zone.

Fig. 16, generally applies to altitudes from sea level to 2134 m (7000 ft), and to the most common special case for indoor thermal environments in which mean radiant temperature is nearly equal to dry-bulb air temperature and air velocity is less than 0.2286 m/s (45 fpm). For this case, the thermal en-



^aThe envelope applies for lightly clothed, sedentary individuals in spaces with low air movement, where the MRT equals air temperature; for other cases, see Fig. 17.

Fig. 16 New Effective Temperature Scale (ET*)

Table 7 Equations for Predicting Thermal Sensation (Y)* of Men, Women, and Men and Women Combined After Exposure Periods of 1, 2, and 3 hr to any Given Dry-Bulb Temperature (t) and Vapor Pressure (P)**

Exposure (hr)	Sex	Regression Equations	
		t = degrees Celsius.	P = vapor pressure, torr.***
1.0	Male	$Y = 0.220 t + 0.031 P - 5.673$	
	Female	$Y = 0.272 t + 0.033 P - 7.245$	
	Combined	$Y = 0.245 t + 0.033 P - 6.475$	
2.0	Male	$Y = 0.221 t + 0.036 P - 6.024$	
	Female	$Y = 0.283 t + 0.028 P - 7.694$	
	Combined	$Y = 0.252 t + 0.032 P - 6.859$	
3.0	Male	$Y = 0.212 t + 0.039 P - 5.949$	
	Female	$Y = 0.275 t + 0.034 P - 8.622$	
	Combined	$Y = 0.243 t + 0.037 P - 6.802$	

*Y values will range from -3 to +3 where -3 is cold; -2 is cool; -1 is slightly cool; 0 is comfortable; +1 is slightly warm; +2 is warm; and +3 is hot.

**For young adult subjects with sedentary activity and wearing a clothing ensemble with a thermal resistance of approximately 0.5 clo, MRT = DBT and air velocities are <0.2 m/s.

***To convert torr (mm Hg, 0°C) to pascals, multiply by 133.322.

Table 8 Predicted Mean Vote⁸

Clothing clo†	Amb. Temp., °C	Relative Velocity (m/s)			
		<0.1	0.2	0.3	0.4
0.5	23	-1.1	-1.51	-1.78	-1.99
	24	-0.72	-1.11	-1.36	-1.55
	25	-0.34	-0.71	-0.94	-1.11
	26	0.04	-0.31	-0.51	-0.66
	27	0.42	0.09	-0.08	-0.22
	28	0.80	0.49	0.34	0.23
	29	1.17	0.90	0.77	0.68
	30	1.54	1.30	1.20	1.13
0.75	21	-1.11	-1.44	-1.66	-1.82
	22	-0.79	-1.11	-1.31	-1.46
	23	-0.47	-0.78	-0.96	-1.09
	24	-0.15	-0.44	-0.61	-0.73
	25	0.17	-0.11	-0.26	-0.37
	26	0.49	0.23	0.09	0.00
	27	0.81	0.56	0.45	0.36
	28	1.12	0.90	0.80	0.73
1.00	20	-0.85	-1.13	-1.29	-1.41
	21	-0.57	-0.84	-0.99	-1.11
	22	-0.30	-0.55	-0.69	-0.80
	23	-0.02	-0.27	-0.39	-0.49
	24	0.26	0.02	-0.09	-0.18
	25	0.53	0.31	0.21	0.13
	26	0.81	0.60	0.51	0.44
	27	1.08	0.89	0.81	0.75

†One clo equals $0.155 \text{ m}^2 \cdot ^\circ\text{C}/\text{W}$.

environment is well specified by the two variables shown: dry-bulb air temperatures and rh.

The KSU-ASHRAE Comfort envelope applies for occupants wearing clothing of 0.4 to 0.6 clo insulation⁷² and contrasts with the 0.5 to 0.7 clo values assumed in ASHRAE Comfort Standard 55-74. For the KSU data, the activity is classified as sedentary (1 met). In Standard 55-74, office work (1.0 to 1.2 met) was the design activity. These small differences in activity level and clothing insulation account for the 1.5°C (3 deg F) displacement of the KSU-ASHRAE envelope above the Standard 55-74 zone.

A wide range of environmental applications is covered by ASHRAE Comfort Standard 55-74. Offices, homes, schools, shops, theatres, etc. can be approximated with these specifications. The Standard specifies an environmental range for comfort based on available research data and field judgments of the Standard's subcommittee members as of 1974.

Design data given in the KSU equations (Table 7) define conditions which maximize thermal acceptability of the environment for a large group of similarly clothed, active adults and will minimize the fraction of potential complainers among the space occupants.

In place of the old effective temperature (ET) lines, the new ET* loci from Fig. 15 are plotted in Fig. 16. This chart is primarily useful in the usual *comfort range* for sedentary, lightly clothed people, and secondarily at higher temperatures where sedentary heat stress is involved. Although the ET* scale is based on 1-h exposure, previous data⁷⁵ show no changes (of engineering importance) in response due to longer exposures unless the limits of heat stress ($\text{ET}^* > 32^\circ\text{C}$ or 90 F) are approached.

The ET* lines show a moderate humidity effect on thermal comfort itself. Its effect on discomfort increases as both the thermal level of the environment and regulatory sweating increase. Man's total evaporative heat near the comfort range is only about 25% of total heat loss. As the thermal level increases, this percentage grows; evaporation accounts for 100% of the heat loss as the environmental temperature equals and rises above skin temperature of 35°C (or 95 F).

The new ET* scale is labeled as the dry-bulb temperature at the *intersection* of loci of constant physiological strain with the 50% rh line. For dry-bulb temperatures above 24°C (75 F), this choice gives Index temperature values which feel more accurate to engineers and the public, since most practical environments are usually much nearer 50% than 100% rh. The old ET, indexed by the dry-bulb at 100% rh, resulted under practical conditions in temperatures always lower than the actual dry-bulb temperature. The new Index, if used for laymen in reporting indoor and outside weather conditions, may result in better public acceptance of environmental control.

To summarize, data in Fig. 16 is useful for light clothing and seated or sedentary activity. ASHRAE Comfort Standard 55-74 generally applies for average clothing and activity. The KSU-ASHRAE equations are useful in evaluating the environment for lightly clothed subjects, resting and working at a desk. The most commonly recommended design conditions for comfort where the two zones overlap are therefore:

$\text{ET}^* = 24.5^\circ\text{C}$ or 76 F

Dry-bulb air temperature = MRT = 24.5°C (76 F)

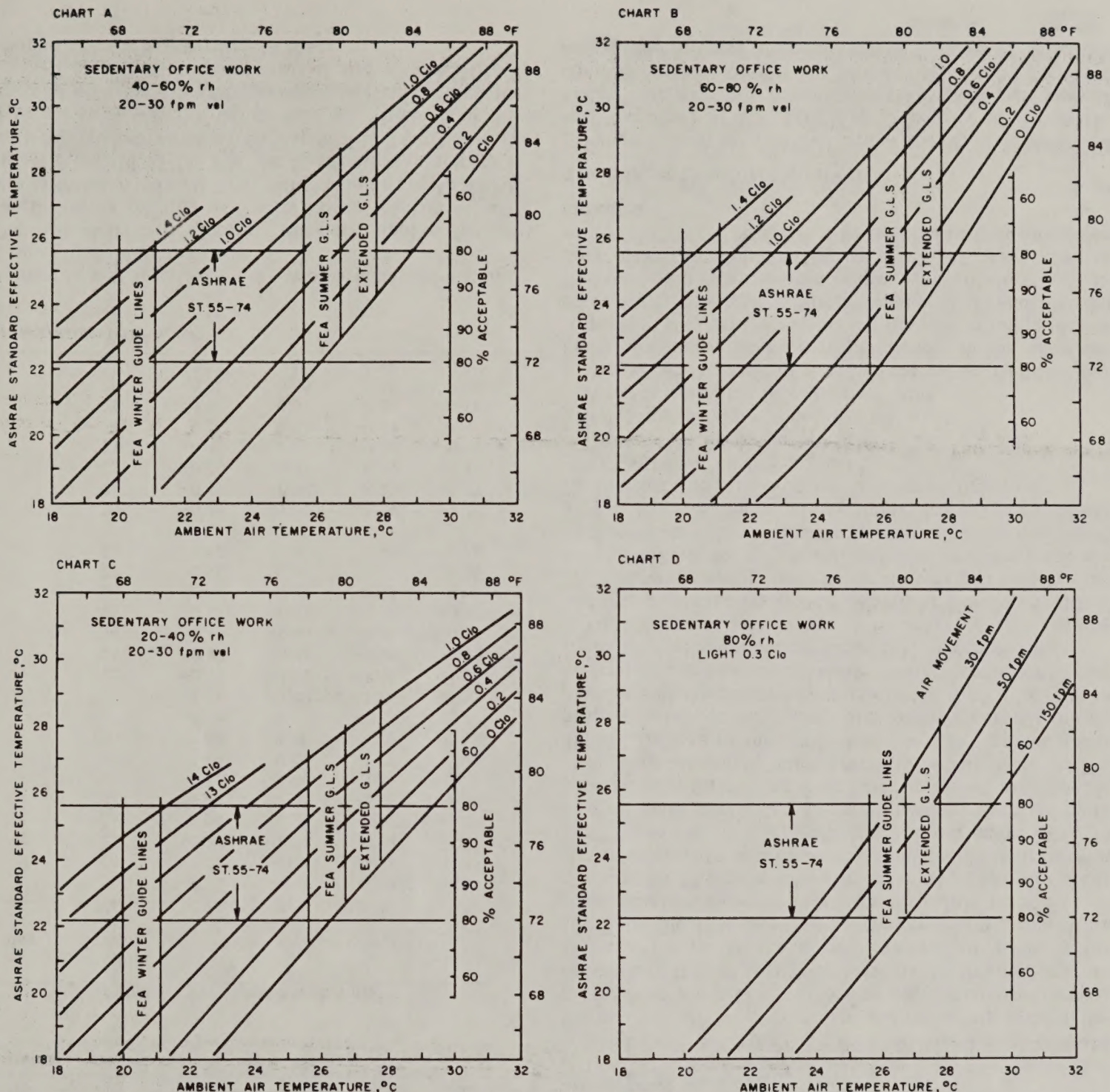
Relative humidity = 40% (20 to 60 range)

Air velocity less than 0.23 m/s (45 fpm)

With increasing need to conserve energy, adjustments may be mandated by the Federal government in the allowable winter and summer thermostat settings. The resulting degree of comfort, presented as the percentage of individuals who find the condition acceptable wearing standard shirtsleeve indoor office clothing (0.6 clo), is in Fig. 17. The extent to which comfort can be achieved by clothing adjustments is also indicated.

The Fanger Comfort Equation

Fanger's study on comfort⁸ began at KSU in 1966-67 and was continued at the Technical University of Denmark. Fanger's objective was to generalize the physiological basis of comfort so that comfort for any activity can be predicted analytically in terms of environmental parameters. His com-



^a The range for 80% acceptable is shown by two horizontal lines between 72 and 78 F (22.2 and 25.6°C) on ordinate, as specified by Standard 55-74A. Chart A describes conditions for normal air movement and average humidity; for the locus with 0.6 clo, ET^* always equals T_a by definition; Chart B describes conditions with high humidity, as might occur during summer in New York or the tropics; Chart C covers low humidity conditions, as would occur indoors in winter or in desert areas; Chart D shows the effect of air movement, such as would be expected from a ceiling fan. For practical application of charts, optimum clothing insulation is shown that should be worn when offices are conditioned under FEA Summer and Winter Guidelines' temperatures necessary for energy conservation.

Fig. 17 Evaluation of ASHRAE Standard ET^* for Sedentary (Office Work), in Terms of Ambient Air (or Adjusted Dry-Bulb) Temperature, Clothing Insulation (I_{cl}), Relative Humidity, and Air Movement^a

fort equation is based on a rationally derived heat balance equation for the passive state during thermal equilibrium and on the two experimental observations that during a state of comfort (defined by a neutral temperature sensation) a unique relation exists between the level of activity described by

metabolism and both $\bar{t}_{sk}$ (for comfort) and E_{rsW} (for comfort). His predictive equations for a comfortable $\bar{t}_{sk}$ and E_{rsW} are:

$$\bar{t}_{sk} = 35.7 - 0.0372M \text{ in } ^\circ\text{C and W/m}^2 \quad (57)$$

$$E_{rsW} = 0.42(M - 58.2) \text{ in W/m}^2 \quad (58)$$

For sedentary conditions (1 met, 58.2 W/m² or 50 kcal/h·m²), comfort values for $\bar{t}_{sk}$ and E_{rsW} are 34°C (93.2°F) and zero, respectively. During exercise ($M > 1$ met), $\bar{t}_{sk}$ drops and E_{rsW} increases in accordance with current observations on exercising, for clothed and unclothed subjects.^{58,75,76}

The heat balance equation (Eq 29) at thermal equilibrium ($S = 0$) is essentially a function of the following form:

$$f(M, \text{clo}, E, \bar{t}_{sk}, v, \text{MRT}, t_a, \text{and } P_a) = 0 \quad (59)$$

When Eq 57 and 58 are substituted in Eq 59, Fanger's Comfort Equation, a new function, results:

$$f(M, \text{clo}, v, \text{MRT}, t_a, \text{and } P_a) = 0 \quad (60)$$

From a comfort equation so derived, it is possible to predict any combination of environmental factors (i.e., t_a , MRT, v , and p_a) that produce a "comfortable" environment for a clothed (clo) person performing any selected activity (M). Either refer to Fanger's original equation,⁸ or use Fanger Comfort Charts, which are computer solutions of his equation.

The Generalized Comfort Charts (Fanger)

The comfort envelope defined by ASHRAE Standard 55-74 (Fig. 16) applies only for sedentary and slightly active, normally clothed persons at low air velocities, when the MRT is equal to air temperature. For other clothing, activities, air temperatures, etc., the ASHRAE Standard recommends use of Fanger's General Comfort Charts. A selection of these and others are shown in Figs. 16 to 20; a more complete set of charts is given in Ref 8.

In each of these charts, comfort lines have been drawn, i.e., curves through various combinations of two variables which create comfort, provided values of other variables are kept constant. The quantitative influence of clothing, activity, and environmental parameters, given by Fanger's Comfort Equation and shown on the corresponding comfort charts, has been on the whole confirmed by a series of recent studies of the individual parameters.^{75,87-93}

For practical application of the comfort charts, first estimate the activity level and clothing (Tables 1 and 5), taking room use into account. Combinations of the four environmental parameters which provide thermal comfort can then be found from the charts. Application of the comfort charts is illustrated by the following:

Example 1: In an office, employees are clothed at 1 clo (normal business suit) and occupied with sedentary work (1 met). Relative air velocity < 0.1 m/s (19.7 fpm); rh is 50%. Determine the optimal air temperature, presuming mean radiant temperature equals air temperature. **Solution:** From the upper right-hand chart in Fig. 18, $t_a = t_{mrt} = 23.0^\circ\text{C}$ (73.4°F).

Example 2: In a warehouse, air temperature of 14°C (57°F) and 50% rh must be maintained, due to the nature of goods stored. Air velocity is 0.2 m/s (39.4 fpm). The comfort of an occupant performing sedentary work and clothed at 1 clo is to be maintained by means of high intensity infrared heaters placed above his workplace. Calculate the mean radiant temperature necessary for comfort. **Solution:** From the upper, right-hand chart in Fig. 19, $t_{mrt} = 38^\circ\text{C}$ (100.4°F).

Example 3: Under winter conditions, mean radiant temperature in a long-distance bus is calculated to be 5°C (9 deg F) lower than air temperature. Determine air temperature necessary for comfort of passengers seated without top clothing (1.0 clo). Velocity is 0.2 m/s (39.4 fpm); rh is 50%. **Solution:** From the upper, right-hand chart of Fig. 19, $t_a = 25.5^\circ\text{C}$ (77.9°F) and $t_{mrt} = 20.5^\circ\text{C}$ (68.9°F).

Example 4: Determine comfort temperature for personnel in a shop where the mean activity corresponds to walking at a speed of 1.5 km/h (0.9 mi/h) (activity = 1.5 met, relative velocity = 0.4 m/s or 78.7 fpm; clothing = 1.0 clo; rh is 50%). **Solution:** From the lower chart in Fig. 20, $t_a = t_{mrt} = 20.8^\circ\text{C}$ (69.4°F).

Example 5: In a "clean room" (laminar flow type), horizontal air velocity is 0.5 m/s (98.4 fpm); rh is 50%. Personnel are engaged in sedentary work, clothed in a special standard suit (1.0 clo). Determine comfort temperature. **Solution:** From the lower chart in Fig. 20, comfort temperature is 24.7°C (76.5°F).

Predicted Mean Vote (PMV)

In practice, when evaluating the thermal climate of a room, thermal parameters must first be measured at a suitable number of points in the occupied zone. Deviations from the optimal condition given in the comfort charts can then be determined.

It is, however, often of value to quantify the degree of discomfort. For this purpose, an index has been devised,⁸ giving the predicted mean vote (PMV) of a large group of subjects according to the following psychophysical scale:

- 3 = cold
- 2 = cool
- 1 = slightly cool
- 0 = neutral
- + 1 = slightly warm
- + 2 = warm
- + 3 = hot

The PMV is a complex mathematical function of man's activity, clothing, and the four environmental parameters. It can, however, be easily determined from a comprehensive table in Ref 8, an extract of which appears here as Table 8.

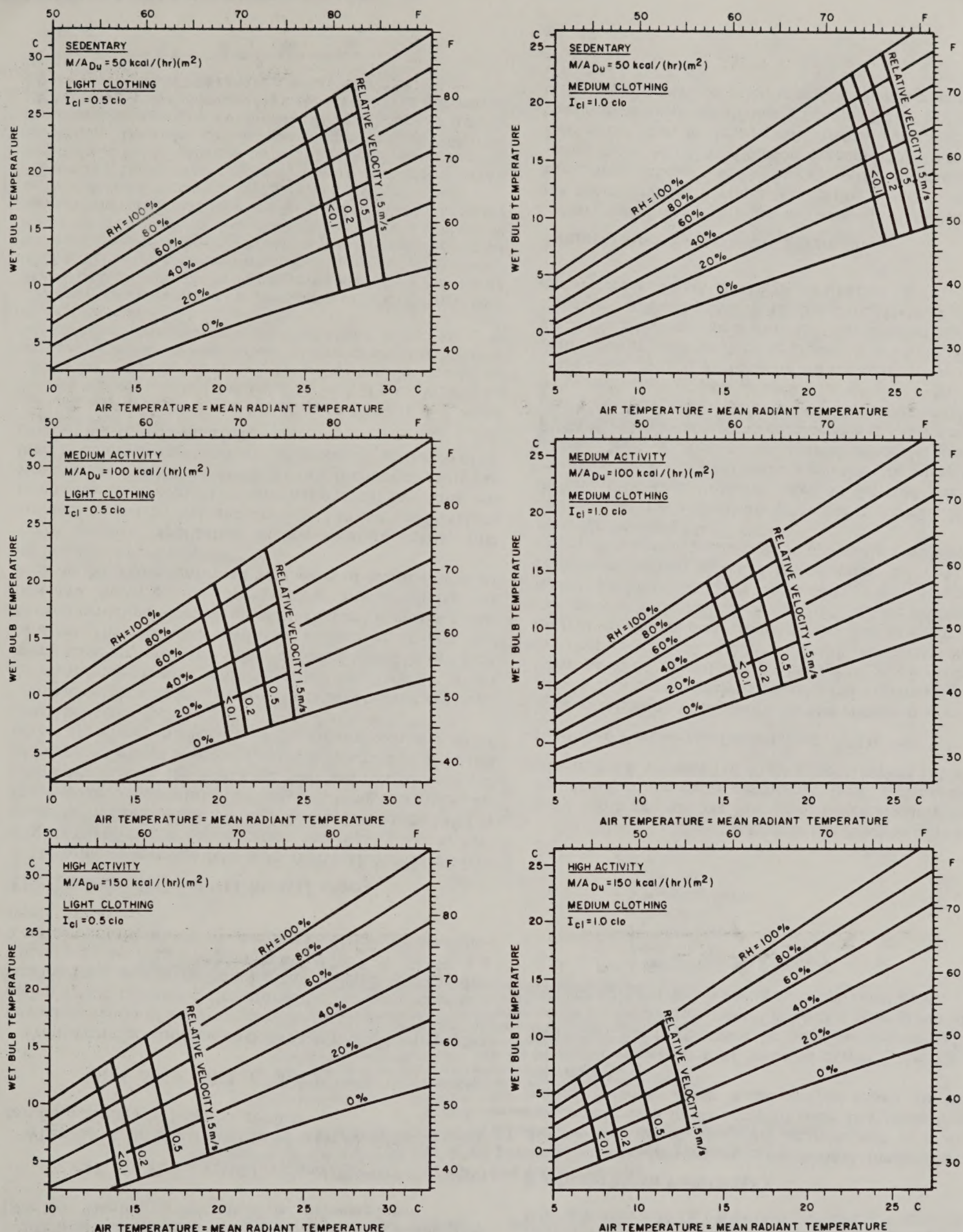
Predicted Percentage Dissatisfied (PPD)

In an extension of his study, Fanger employed a technique known as a probit analysis, developing a nomogram from which he could estimate the percentage of people dissatisfied (i.e., voting - 3, - 2, + 2, or + 3) with the thermal environment at various temperature conditions. Rohles et al⁷⁴ applied this analysis to the KSU data and predicted the percentage of dissatisfied individuals, i.e., those voting warm, hot, cool, or cold under various effective temperatures, ET*. As stated earlier, the lowest percentage of dissatisfied subjects is expected to be about 5%.

Results of this analysis are presented in Fig. 21. Note the difference between slopes of lines on the cold side of the minimum PPD compared to the warm side; the interpretation is that, from a comfortable thermal condition (minimum PPD), people get colder than comfortable at a faster rate than they get warmer than comfortable. This nomogram (Fig. 21) is for sedentary subjects dressed in a 0.6-clo ensemble. The curve is assumed to shift downward for activity levels higher than sedentary and for clothing greater than 0.6 clo. This will place the effective temperature ET* for comfort within the range prescribed by ASHRAE Standard 55-74. For direct measurement of PMV and PPD, see Chapter 13.

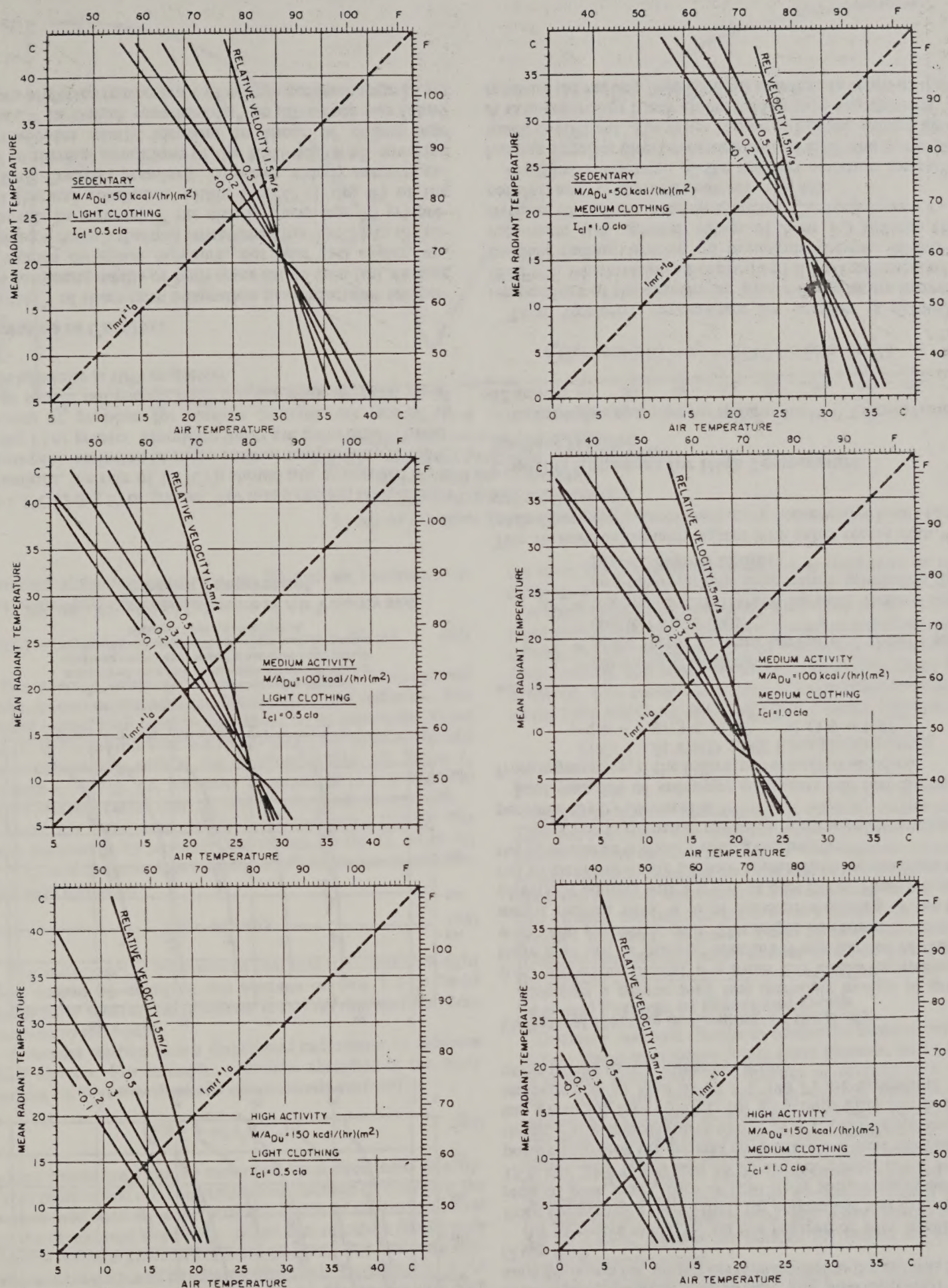
Temperature and Humidity Fluctuations

Environmental temperature and humidity often fluctuate as the control system operates the heating or air-conditioning equipment. Studies⁷⁷ show that allowable fluctuating limits stated in the ASHRAE Comfort Standard 55-74 are conservative; and that, in the thermal comfort range, the rate of change of temperature should not exceed 2.2°C/h (4 deg F/h) if the peak-to-peak variation in the dry-bulb temperature cy-



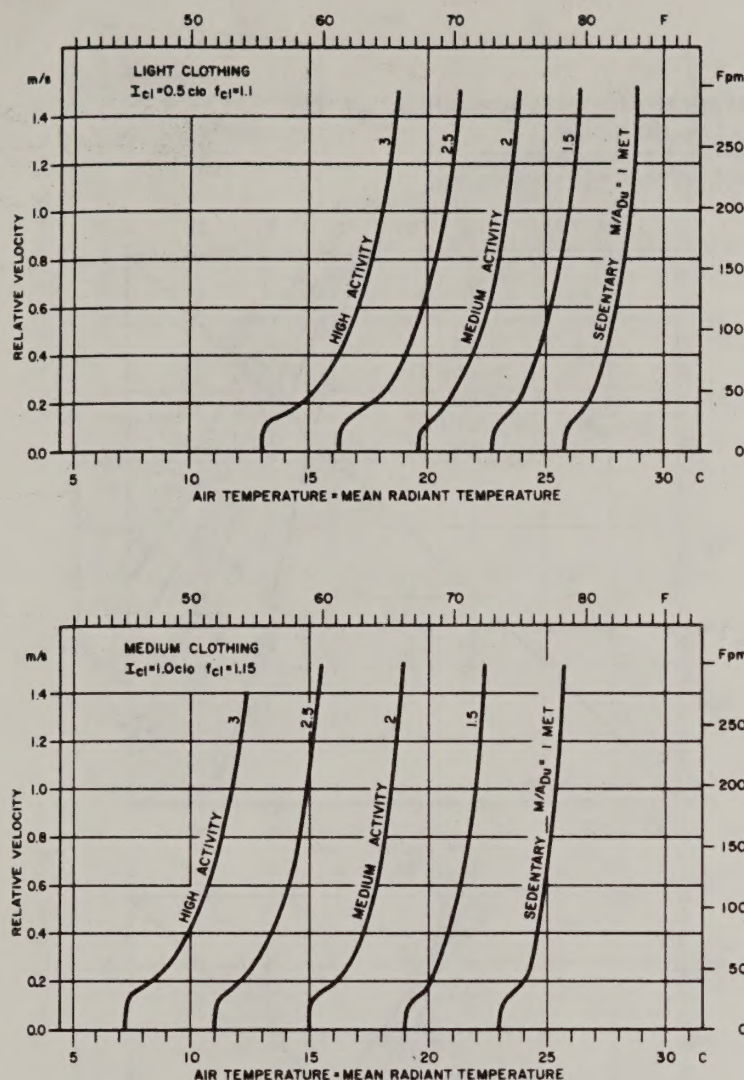
^aThe comfort lines are curves through different combinations of ambient temperature and humidity which provide thermal comfort. The six charts apply to six different combinations of activity and clothing, where air temperature equals mean radiant temperature.

Fig. 18 Combined Influence of Humidity and Ambient Temperature^a



^a The comfort lines are curves through different combinations of mean radiant temperature and air temperature which provide thermal comfort. The six charts apply to six different combinations of activity and clothing at 50% rh.

Fig. 19 Combined Influence of Mean Radiant Temperature and Air Temperature^a



^a The comfort lines corresponding to five different activity levels are curves through different combinations of relative air velocity and ambient temperature which provide optimal thermal comfort. The two charts apply for persons wearing 0.5 and 1.0 clo at 50% rh.

Fig. 20 Combined Influence of Air Velocity and Ambient Temperature^a

clo is 1.1°C (2 deg F) or greater. For mean radiant temperature fluctuations, the rate of 1.7°C/h should not be exceeded if the peak-to-peak variation in mean radiant temperature is 0.8°C (1.5 deg F) or greater. Humidity limits are quite broad, usually posing no problem for modern controls: the rate of rh change should not exceed 20%/h if the peak-to-peak variation in humidity is 10% or greater.

Adaptation to Comfort

A study⁷⁸ of short-term adaptation to comfortable temperatures for young adults of both sexes shows men feel warmer than women on initial exposure, but later feel cooler, approaching women's thermal sensations after 1 to 2 h in the environment. In a survey,⁷⁹ the elderly (mean age 75 yr) preferred thermal conditions within 0.56°C (1 deg F) of the ASHRAE Comfort Standard. However, elderly subjects exposed to thermal conditions of the KSU-ASHRAE envelope had responses nearly identical to those of college age subjects.⁸⁰ In Danish experiments,⁸ no difference was found between preferred temperature of college age (mean age 23 yr)

and elderly (mean age 68 yr) subjects. Man's comfort conditions seem independent of the time of day or night.⁹⁴⁻⁹⁶ Shiftworkers preferred the same thermal environment during night work as during the day. Each individual is quite consistent in thermal preference from day to day,⁹⁷ but preferences differ considerably between individuals. The interindividual standard deviation for resting persons clothed at 0.6 clo was 1.1°C (2 deg F).⁹⁸

An extensive study⁸¹⁻⁸⁴ on the relation of foot comfort to floor temperature shows that, for college age and elderly subjects of both sexes, cool or cold floor temperatures between 15.6 and 29.4°C (60 and 85 F) are acceptable for a 3-h exposure provided the general environment is near the comfort range. Floor temperatures above 29.4°C (85 F) elicit votes of too warm for foot comfort for all groups after one h. Floor temperatures as high as 32.2°C (90 F) are acceptable for a one-h period to the college age group.

Unilateral Heating or Cooling of the Body

Although a person may feel thermally neutral in general (i.e., preferring neither a warmer nor cooler environment), there may not be thermal comfort if one part of his body is warm and another is cold. This might be caused by an asymmetric radiant field, a local convective cooling of the body (draft), or contact with a warm or cool floor. Thus, it is essential to establish limits on how asymmetric the heat loss from the body can be without evoking discomfort.

Limits for asymmetric radiation were recently studied experimentally by Olesen et al.⁹⁹

Less than 5% of sedentary occupants will feel discomfort from asymmetry, if the following formula is satisfied:

$$(-2.4 - 1.8I_{cl}) < \Delta t_w F_{p-w} < (3.9 + 1.8I_{cl})$$

where

I_{cl} = clo-value of clothing.

F_{p-w} = angle factor between person and radiant source (see Ref 8 and 100).

Δt_w = temperature difference between radiant source and mean radiant temperature in relation to the person, degrees Celsius.

This formula reasonably agrees with other recent data,^{101,102} while Chrenko¹⁰³ established more conservative limits for hot ceilings 25 yr ago.

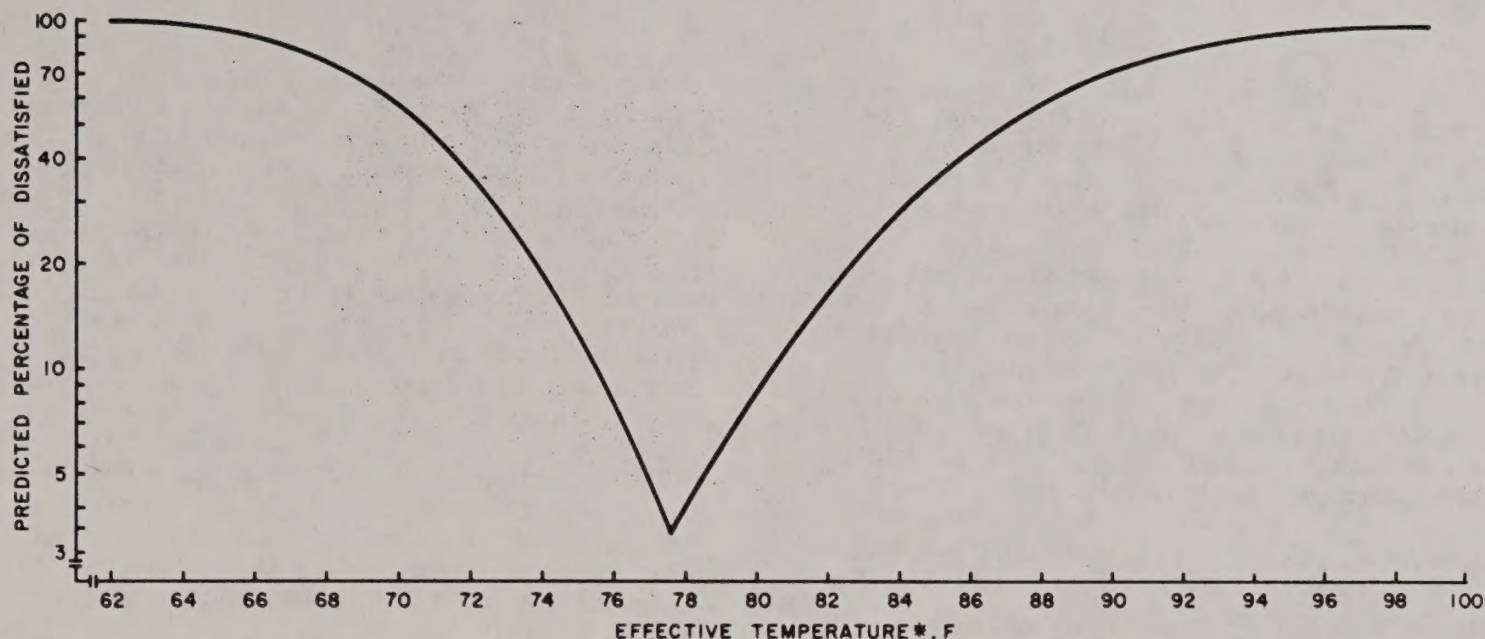
Comfort Equations for High Temperature Radiant Heating

The *comfort equation for radiant heat*^{44,45} follows from Eq 42 and 46:

$$t_o(\text{for comfort}) = t_a + (\text{ERF for comfort})/h \quad (61)$$

Thus, operative temperature for comfort is defined as temperature of the ambient air plus a temperature increment (ERF)/h, which ratio is a measure of the effectiveness of the incident radiant heating on occupants present. Higher air movement (i.e., greater values of h or h_c) reduces effectiveness of radiant heating systems. Clothing lowers t_o for comfort and for thermal neutrality (Eq 46).

Practical application of the comfort equation for radiant heating requires direct measurement of ERF and h, the combined coefficient. The latter can be estimated, using Table 2. A skin-colored or black globe, 0.15 m (6 in.) in diameter, can measure the radiant field ERF for comfort, in terms of the un-



^aBased on 1300 American and European subjects.

Fig. 21 Predicted Percentage of Individuals Who Would Be "Thermally" Dissatisfied (PPD) at Various Levels of Effective Temperature (ET*)^a

corrected globe temperature t_g in °C and air movement in m/s, by the following relation:

$$\text{ERF} = (A_r/A_D) [6.1 + 13.6\sqrt{v}](t_g - t_a) \text{ in W/m}^2 \quad (62)$$

The average value of A_r/A_D is 0.7. For a skin-colored globe, no correction is needed for the quality of radiation. For a black globe, ERF must be multiplied by α , determined from Fig. 6. For a subject with 0.6 to 1.0 clo, t_o for comfort should agree numerically with t_a for comfort in Fig. 16. When t_o replaces t_a in Fig. 16, humidity is measured in mm Hg (Pa) vapor pressure rather than rh, which refers only to dry-bulb.

There are three other methods of measuring (ERF). The most accurate is by physiological means. In Eq 42, when M , $t_s - t_a$, and the associate transfer coefficients are experimentally held constant:

$$\Delta E = \Delta(\text{ERF}) \quad (63)$$

The variation⁴⁴ in evaporative heat loss (i.e., rate of weight loss) caused by changing the wattage of two T-3 infrared lamps is a measure in absolute terms of the radiant heat received by the body.

A second method uses a directional radiometer to measure ERF directly. For example, radiation absorbed at the body surface (in W/m² or Btuh/ft² of total body surface) is:

$$\text{ERF} = \alpha(A_i/A_D)I \quad (64)$$

where irradiance I can be measured by a directional (Hardy-type) radiometer; α is the surface absorptance effective for the source used; and A_i is the projection area of the body normal to the directional irradiance. Eq 64 can calculate (ERF) only for the simplest geometrical arrangements. For a human subject lying supine and irradiated uniformly from above, A_i/A_D varies as 0.3. Fig. 6 shows variance of α for human skin with blackbody temperature (in K) of the radiating source. When irradiance I is uneven and from many directions, as is usually

the case, the previous physiological method may be used to calibrate an effective A_i/A_D from the observed ΔE and $\Delta(\alpha I)$.

A third method of measuring ERF is by direct calculation from radiometric data that give: radiation emission spectrum of the source; concentration of the beam; radiation from floor, ceiling, and windows; and corresponding shape factors involved. This analytical approach is described in Chapter 12 of the 1974 ASHRAE HANDBOOK & Product Directory.

HEALTH AND THE ENVIRONMENT

Introduction

Man's health is in part dependent upon his indoor and outdoor environment. The indoors, where he spends 95% of his time,⁸⁵ is more important to the HVAC engineer because it is at least partially controllable. The main difference between indoor and outdoor atmospheres is in concentration of bacteria and viruses; the concentration is very small outdoors, while greater numbers indoors create greater possibility for transmission among people. Indoor levels of pollution from the outdoor environment are, however, slightly lower.

Seasonal Patterns of Illness and Death

Ordinary seasonal change in temperate climates has an effect on illness prevalence. Most acute diseases, and a number of chronic ones, vary in frequency or severity with time of year; some are present only in certain seasons. Minor respiratory infections such as colds and sore throats are present mainly in fall and winter. More serious ones, such as pneumonia, have a somewhat shorter season in winter. Intestinal infections, e.g., dysentery, typhoid fever, poliomyelitis, are more frequent in summer. This is also true for encephalitis, endemic typhus, and other diseases transmitted by insects, since active periods for insects are limited to favorable temperatures.

Many correlations have been made^{86,108} between seasonal illnesses and the weather. A major objection to this practice is that the correlation may in fact be indirect and need not imply

relationship between the two phenomena. This is demonstrated in the high correlation shown⁸⁶ between incidence of colds and the temperature 0.3 m (0.98 ft) below the earth surface. Certain aspects of health, such as mortality and heat stress in heat waves, and the effects of hot and cold extremes on specific diseases, appear to have a strong physiological basis directly linked to outdoor temperature. It therefore seems better to consider outdoor climate separately from indoor climate, although there is always interaction between the two.

OUTDOOR CLIMATE AND HEALTH

Increased Deaths in Heat Waves

The role of temperature extremes in producing discomfort, incapacity, illness, and death has been studied over many years.¹¹¹ Most of this work has been of a physiological nature, in relation to military duty or work situations requiring such knowledge.⁵² The importance of temperature stress from extreme natural temperature fluctuation, affecting both the sick and well in the community, has not been sufficiently appreciated. A study¹¹² of weekly deaths over many years in large U.S. cities indicates the magnitude of the effect. This study was made to demonstrate the importance of influenza in producing conspicuous periods of excess deaths. The only other factor identified which produced conspicuous epidemics of deaths was heat waves. These had the same amplitude as lesser influenza epidemics, but were of shorter duration (1 wk as compared to 4 to 6 wk). In recent years more attention has been given to this problem; six studies were published, two on the 1966 heat wave.

An epidemiological study of effects of the July 1 to 31, 1966 heat wave in Illinois, was published in 1968.¹¹³ Daily weather data were related to death rates of various age groups in white and Negro populations. Concurrent disease (if any), cause of death, sex, age, and race were compared with a similar period in 1965, a *normal* year for July temperatures. Three heat spells were identified; the first peaked on July 5, the second on July 12, and the last transient spell on July 18. There was a 33% increase in mortality during the first spell, a 36% increase during the second, and a 10% increase in the last period, July 16 to 20. Of the population at risk, people over 65 suffered the greatest mortality, which was attributed largely to lesions of the vascular system of the brain and other circulatory diseases. Circulatory impairment leads rapidly to failure of the physiological thermoregulatory system upon which these individuals were completely dependent. With regard to sex and race, females suffered greater losses than males, and whites more than Negroes; the female Negro population suffered most, the Negro male population least. The study concludes: "The mixed response by age, sex and race...indicates that the impact of an intense heat wave produces very complex results."¹¹³

The relationship¹¹⁴ of health data to comfort data can be visualized on a diagram of wet-bulb vs dry-bulb temperatures (Fig. 22). The ASHRAE comfort zone lies between ET^* 22°C (71.6 F), slightly cool, and ET^* 27°C (80.6 F), slightly warm. ET^* loci are also drawn for $w = 0.25$, $w = 0.50$, and $w = 1.0$. The *Danger Line for Heat Stroke* used by Ref 113 roughly coincides with the ET^* 34 to 36°C (93.2 to 96.8 F) for $w = 0.40$ to 0.50. ET^* loci are lines of constant physiological strain on the human thermoregulator, and correspond to constant levels of thermal discomfort of: *slightly uncomfortable*; *uncomfortable*; and *very uncomfortable*. Fig. 22 illustrates thermal discomfort very closely follows physiological strain.

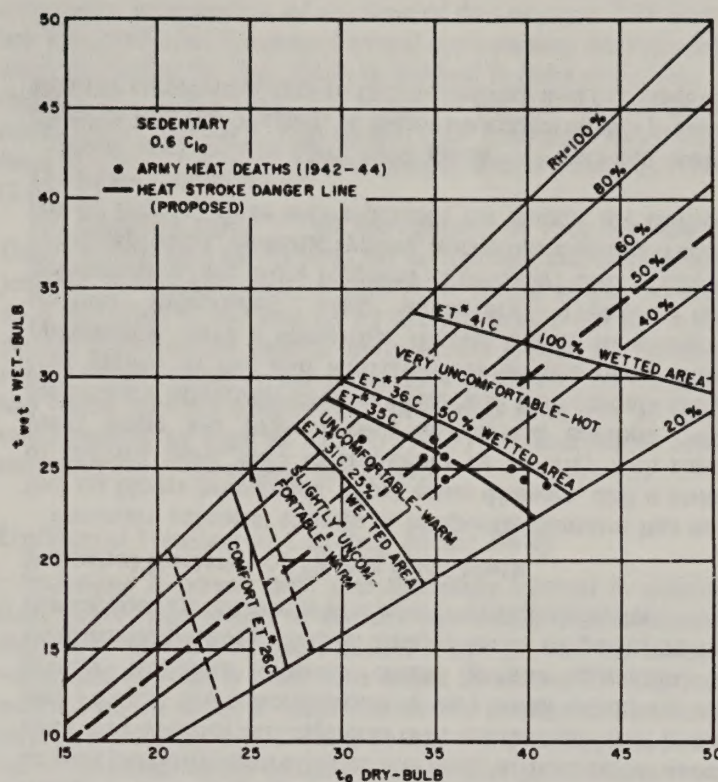


Fig. 22 Comfort and Discomfort Lines, Lines of Equal Wetted Area (Physiological Strain). Lines for ET^* at Comfort, 25%, 50%, and 100% Wettedness Also Indicated

The heat stroke deaths noted near the ET^* 35 to 36°C (95 to 96.8 F) zone are from data¹¹⁵ based on the military files of 1944 for U.S. soldiers assigned to sedentary duties in mid-western Army Camp offices. These data closely parallel the physiological strain in presumably active, healthy men associated with the requirement for prolonged sweating at $w = 0.5$. The earlier study¹¹³ indicated, during the first six days of July 1966, dry-bulb temperatures averaged near 29°C (84.2 F), and wet-bulb near 22.2°C (72 F) ($ET^* = 29.5^\circ\text{C}$ or 85.1 F). The number of deaths during this period increased 33% over that for the same period of the previous year. Most deaths were in the 65-and-over group, although other age groups also suffered. Note a line of constant ET^* of 29.5°C corresponds to a slightly uncomfortable level. It is curious that increase in death rate, with several heat stroke deaths, was below the *Danger Line*; and that the second heat wave, which corresponded to an ET^* of 34°C (93.2 F) had only a 36% increase in deaths.

There could be several explanations for these observations. For example, it is possible that many of the infirm were carried away by the impact of the first heat wave on an essentially unacclimatized population. Also, by the time the second and third heat waves occurred, the population may have developed a significant degree of heat acclimatization, perhaps sufficient to save many lives. A third explanation could be the increase in sales and installation of air-conditioning equipment, and the taking of other precautions against the heat. In this connection, a series of studies of heat-related deaths¹¹⁶ using data collected in the 1939, 1955, and 1963 heat waves in Los Angeles are of interest. It was found that their prediction equation for mortality, using age and a one-day lag in temperature, held for all years except 1963, which failed to



United States
Department of
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Agricultural
Research
Service

Southern Region
Southern Plains
Area

Screwworm Research Lab
Apartado Postal #544
Tuxtla Gutierrez, Chiapas
Mexico

April 26, 1984

SUBJECT: Request for A-82 Crawl-off Larvae

TO: Mr. Raul Marroquin
Chief of Production

As I mentioned by telephone we would like to obtain A-82 crawl-off larvae from the larva-water separator in the mass production plant for use in some pupation experiments in our laboratory. Specifically we would like to obtain approx. 2 liters of larvae tomorrow April 27 between 8 am and noon. If you approve this request, Dr. W. L. Rubink will carry containers of sawdust into the plant, put the larvae on sawdust, seal the containers and carry them directly to the ARS laboratory.

We have had some rather grave rearing problems in our lab this month and are currently examining 5 possible causes. Dr. Rubink proposes to compare the pupation of A-82 and VF-84 under different moisture conditions. As always your help and cooperation is sincerely appreciated.

O.H. GRAHAM
Location/Project Leader

cc:
W. L. Rubink
D. B. Taylor

